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The Tertiary Echinoids of South-Eastern Australia
IV. Camarodonta (2)

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Abstract

The following Australian Tertiary diadematacioid regular echinoids are described and figured: *Evechinus palatus* sp. nov., *Cryptechinus humilior* (Bittner) gen. nov., *Asaphechinus murrayensis* gen. et sp. nov., *A. princeps* sp. nov., *A. singletoni* sp. nov., *A. tasmanensis* sp. nov., *Grammechinus meridionalis* sp. nov., *Ortholophus lineatus* (Duncan), *O. bittneri* nom. nov., *O. morganensis* sp. nov., *O. pulchellus* (Bittner), *O. venustus* sp. nov., *O. woodsi* (Laube), *Pseudechinus* sp. cf. *P. albocinctus* (Hutton), *Paradoxechinus novus* Laube, *Tatechinus nudus* gen. et sp. nov. The sexual dimorphism of the test of *P. novus* is described and discussed.

Introduction

This paper concludes the description of the regular echinoids of the Tertiary strata of SE. Australia. Included in this part are the temnopleurids and an additional echinometrid which was discovered in the collections of the National Museum of Victoria subsequent to the writing of Part III. As in previous parts (Philip 1963, 1964, 1965b) the ages of the different strata are given in terms of local stages. Concerning these, reference should be made to Ludbrook's (1967) recent review of the correlation of the Tertiary rocks of the Australasian region. The continued assistance of individuals acknowledged in previous parts must be mentioned. Also latterly, Mr T. Darragh, Curator of Fossils in the National Museum of Victoria, has assisted in arranging the loan of material.

During the tenure of a Royal Society and Nuffield Foundation Commonwealth Bursary (1965-1966) it was possible for me to visit Vienna to restudy and photograph Laube's types in the Naturhistorisches Museum.

Systematics

Suborder Echinina Claus
Family Echinometridae Gray
Genus **Evechinus** Verrill

Evechinus Verrill 1871, p. 583.
Evechinus Verrill, Mortensen 1943b, p. 297 *et seq.* (*cum synon.*); McRae 1959, p. 205.

Type Species: *Echinus chloroticus* Valenciennes, by original designation.

Diagnosis: Moderately large, thick tested echinids with trigeminate ambulacral plates, which possess a primary tubercle on every second, third or fourth superambital plate in each column. Poriferous tract broad, with pore-pairs arranged in three vertical series which may become ill-defined adapically. A vertical series of secondary tubercles occurs toward the adradial side of the poriferous tract. Poriferous tracts not widened aborally but around the peristome the ambulacra are wider than the interambulacra. Primary interambulacral tubercles large and usually with enlarged secondary tubercles forming parallel vertical series.

DISTRIBUTION: *Evechinus chloroticus* (Val.), the only species of this genus so far discriminated, is the common littoral urchin inhabiting present-day New Zealand coasts. It is distributed from the Kermadec Islands in the north and to Stewart Island in the south. It also occurs in the Chatham Islands. Farquhar (1894, p. 195) records the species from 'Pliocene formations at Wanganui' and Fell (1954) states that *Evechinus* occurs in the 'lower Nukumaruan' of New Zealand.

REMARKS: The occurrence of this common New Zealand echinoid genus in the Miocene/Pliocene of Australia is particularly noteworthy. It tends to indicate that the genus immigrated from Australia to New Zealand in the early Pliocene and therefore supports the conclusion that a west-to-east trans-Tasman migration of echinoderms has taken place in the late Cainozoic (Fell 1954).

Evechinus palatus sp. nov.

(Pl. 16, fig. 1-6)

DIAGNOSIS: A species of *Evechinus* in which the subambital ambulacral triads all possess primary tubercles.

TYPE SPECIMEN: Holotype and only known specimen: P23967, 'Above nodule bed, west of boat-shed, Beaumaris', Black Rock Member of Sandringham Sands, Cheltenhamian (Coll. F. A. Cudmore).

DESCRIPTION: The test is rounded in outline, with a flattened oral surface somewhat sunken around the peristome.

The pore-pairs lack a triserial character adapically, but this is progressively developed toward the ambitus, so that here and on the aboral surface they are regularly triserial. At and above the ambitus every second ambulacral triad lacks a primary tubercle, but beneath the ambitus primary tubercles are present on each triad. A vertical series of secondary tubercles is present on the adradial side of each poriferous tract. At the ambitus the ambulacra are 60% of the width of the interambulacra.

The interambulacra possess a regular vertical series of moderately large, smooth primary tubercles, which toward the ambitus are joined by an irregular inner and outer series of enlarged secondary tubercles. The rest of the plates are covered by closely spaced secondary tubercles and granules. The gill slits are well defined, although shallow. The perignathic girdle consists of united auricles connected by low apophyses. The apical system is unknown.

MEASUREMENTS OF HOLOTYPE:

h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
34·5 mm	16·0 mm	*c* 6·0 mm	10·5 mm	32(33)	17(18)

REMARKS: McRae's (1959) extensive study of *Evechinus chloroticus* facilitates comparison of *E. palatus* with that species. The new species differs in that:

1. The triserial character of the ambulacral pore-pairs is only clear beneath the ambitus.
2. Each of the subambital ambulacral plate bears a primary tubercle.
3. The secondary tubercles are smaller.
4. There are fewer ambulacral plates which are therefore relatively higher. There are 32 per column in the holotype of *E. palatus*, whereas in *E. chloroticus*

Mortensen (1943b) lists between 42 and 49 in specimens of the type species of comparable size. The triserial ambulacra of *E. chloroticus* are a function of the lower ambulacral plates.

As the ambulacra of *E. palatus* are less specialized than those of *E. chloroticus* it may be directly ancestral to the living species.

Suborder Temnopleurina Mortensen

Family Temnopleuridae A. Agassiz

1. Introduction

Present-day temnopleurids are almost exclusively confined to tropical and subtropical seas. In the Western American region the family appears to be unrepresented, but it is particularly abundant throughout Indo-Pacific waters. The group is known to extend back to the Cretaceous, but is not well represented in the fossil record except in Cainozoic rocks of the Indo-Pacific and Australasian regions. Therefore the perplexing taxonomy of fossil temnopleurids has received but scant attention.

As in other groups of regular echinoids, subdivision of the living representatives of the family depends largely on features which are lost in fossilization. Much previous work on fossil temnopleurids has been concerned with minor details of the sculpture or ornament for the purposes of taxonomic discrimination—which features are acknowledged to be exceedingly variable in adequately known living species. Thus Mortensen (1943a, p. 81) observes of *Temnopleurus toreumaticus* (Leske), 'The differences . . . in the shape of the test, the development and number of tubercles, as well as in the size of the sutural pits, are so considerable that looking at extremes one would hardly think it possible that it all could be one and the same species.' H. L. Clark (1925, p. 83) gives measurements for this species which indicate that, in mature specimens, the v.d. may vary between 47% and 73% of the h.d.

It would seem that extremely wide intraspecific variation in such features is widespread throughout the family. Sculpture, in particular, may also vary considerably with growth, for even highly sculptured juveniles may develop into obscurely, or even unsculptured adults (reported in the living genera *Pseudechinus* and *Desmechinus* and seen in many of the Australian Tertiary species).

Different palaeontologists appear to have answered the problem of variation in fossil temnopleurid species in a similar fashion, *viz.*, by naming extremes of variation in an assemblage (*i.e.*, forms taken from the same locality and horizon) as separate species. D'Archiac and Haime (1853) and Duncan and Sladen (1883) would seem to have done just this with the Indian Tertiary species (*e.g., Temnechinus costatus* d'Archiac, *T. rousseaui* d'Archiac, *T. tuberculosus* d'Archiac and Haime, *T. affinis* Duncan and Sladen 1883, pp. 84-87; Pl. 13, figs. 9-17). A similar, although more exacting treatment was apportioned the Miocene temnopleurids of Java by Jeannet (*in* Jeannet and Lambert 1935). Here, from the same horizon and locality, Jeannet discriminated the following forms:

Dicoptella agassizi Lambert and Thiéry, *Dicoptella agassizi* var. *tenius* (4 specimens), *Dicoptella agassizi* var. *elevata* (4 specimens), *Dicoptella deupoldi* Jeannet (1 specimen), *Dicoptella tobleri* Jeannet (4 specimens, including one illustrated as '*D.* cf. *tobleri*'), *Dicoptella java* Jeannet (1 specimen). There can be no doubt that all of these (well described and figured) represent a single, variable species (= *Temnotrema macleyanna* (T. Woods), originally described from the Miocene of Yule Island, New Guinea by Woods 1877). It is even very likely that the subgenus

Paradicoptella, based on the species *P. rutteni*, is a further variant of this. Thus it appears that one subgenus, five species and two varieties were proposed to cover the variation in what one must suggest is but a single species.

In the Australian Tertiary species described below, an attempt has been made to characterize the extremely wide specific variation which occurs.

2. Classification

Mortensen (1943a) divided the family Temnopleuridae into three subfamilies, *viz.*, Temnopleurinae Duncan, Trigonocidarinae Mortensen, and Genocidarinae Mortensen.

The validity of this subdivision may be questioned, for, in the final analysis, it rests merely with the character of the pedicellariae. It seems likely that the groupings should not stand in formal classification and they certainly cannot be applied to fossil material. In dealing with fossil temnopleurids it is convenient to distinguish two groups on the basis of test morphology, *viz.*:

a. Sculptured temnopleurids
(Mortensen's (1943a) Genocidarinae + Trigonocidarinae + *Pseudechinus*)
b. Temnopleurids with pitted sutures
(Mortensen's (1943a) Temnopleurinae – *Pseudechinus*).

All of the Australian Tertiary species are sculptured temnopleurids. Elsewhere, in the Tertiary of the Indo-Pacific region, the pitted sutured temnopleurids were well represented, or were even the dominant temnopleurid group.

3. Australian Tertiary Temnopleurids

The Australian Tertiary temnopleurids are most imperfectly known. At the end of the last century two genera, six species and one variety had been proposed. Tate (1892, p. 191), however, considered there to be but two variable species, *Paradoxechinus novus* Laube and *Psammechinus woodsi* Laube, and this view has been followed by most later workers (*e.g.* H. L. Clark 1946). More recently, Fell (1949, 1964b) has described two further species, but with only passing reference to earlier work (Philip 1966).

Preliminary examination of the present collections (in which the obvious character of sculpture was emphasized to the exclusion of other features) suggested that even Tate had been too liberal. However, more searching examination of the material, in which progressively less emphasis was placed on detail of the sculpture and more on other features, such as the character of the tubercles (smooth, faintly or strongly crenulate) and the apical system, the development of gill slits, the nature of the perignathic girdle and the ambulacra, and special idiosyncrasies of some forms (the apical depression of *Paradoxechinus novus* and the bare sutures of *Tatechinus nudus* gen. et sp. nov.), led to the recognition of no less than 15 species (9 new) accommodated in seven genera, three of which are new.

Genus **Cryptechinus** gen. nov.

Type Species: *Psammechinus* (?) *humilior* Bittner 1892, pp. 337-338; Pl. 1, fig. 3.

Diagnosis: Comparatively large, sculptured temnopleurids with strongly crenulate tubercles and sharp gill slits. The pore-pairs of the ambulacra are uniserial, and the apical system is dicyclic. Strongly developed radiating sculpture on each plate may be lost during growth. The perignathic girdle consists of styliform auricles not united above the ambulacra.

REMARKS: Among the sculptured temnopleurids discussed by Mortensen (1943a), the living genus *Asterechinus* Mortensen alone possesses distinctly crenulate tubercles, and this genus in other respects is quite unlike *Cryptechinus* (the characters of *Asterechinus* are reviewed below in discussion of *Asaphechinus*). The large size, the general pattern of the sculpture which may be lost on growth, the well-developed gill slits and the non-united auricles, suggests comparison of *Cryptechinus* with the living genus *Desmechinus* H. L. Clark. In this genus, however, the pore-pairs of the ambulacra are strongly arcuate, the posterior oculars of the apical system are usually insert, and, most fundamental of all, the tubercles are smooth. *Cryptechinus* undoubtedly is most closely related to *Asaphechinus* gen. nov. described below, and perhaps this latter genus should merely be considered as a subgenus of *Cryptechinus*.

Mention should be made of the N. American Eocene species *Orthechinus pretiosus* W. B. Clark (*in* Clark and Twitchell 1915, p. 118; Pl. 56, fig. 2a-b). The illustrations of this form recently placed in the genus *Brochopleurus* by Cooke (1959) who also regarded *Gagaria americana* W. B. Clark (*op. cit.* p. 159; Pl. 73, fig. 8a-b) as its synonym. However, *Gagaria americana* was originally described as possessing perforate, crenulate tubercles, which suggests glyphocyphid rather than temnopleurid affinities for the species. Until these forms are more completely known, particularly in the character of the compounding of the ambulacra, the true affinities of the American forms cannot be decided.

The generic name, from κρυτος, *hidden*, refers to the fact that, although the peculiarities of the type species were made known over seventy years ago, the species has been neglected as a synonym of *'Psammechinus' woodsi* Laube by Australian workers ever since.

Cryptechinus humilior (Bittner)

(Pl. 3, fig. 1-9; Pl. 4, fig. 1-6; Fig. 1a-k)

Psammechinus (?) *humilior* Bittner 1892, p. 337-338; Pl. 1, fig. 3.
Psammechinus woodsi Laube, Tate 1892, p. 191 (*partim*).
Echinopsis humilior (Bittner), Lambert and Thiéry 1910, p. 185.
Pseudechinus woodsi (Laube), H. L. Clark 1946, p. 323-324 (*partim*).
(*Non*) *Psammechinus woodsi* Laube 1869, p. 185-186, fig. 1-1b.

DIAGNOSIS: As for genus.

MATERIAL: Twenty-six specimens, fifteen of which retain their apical systems.

TYPE SPECIMEN: Although Bittner gave no locality for his species, on Tate's (*loc. cit.*) authority his two specimens came from the Murray River Cliffs. The specimen which he illustrated in Pl. 1, fig. 3 is here chosen as lectotype. The specimen is lost (I, p. 183). As neotype P17966 is selected. The specimen is from the mid-Miocene Morgan Limestone at Morgan.

DESCRIPTION: The test is comparatively large and depressed with a somewhat flattened adoral surface. The straight poriferous tracts are somewhat sunken, and adorally the test is more closely tuberculated. The peristome is wide, with small, sharp, well-buttressed gill slits. The girdle consists of high separate styliform auricles connected by low apophyses.

The apical system is small and dicyclic, with elongate oculars and with the anterior oculars more exsert than the posterior, particularly ocular 1. The madreporite is not markedly enlarged, and the raised porous area extends over most of the surface of genital 2. The genital pores are large, notably so in four specimens. Each of the genitals is ornamented by three to six secondary tubercles arranged in

irregular series bordering the peristome. A single tubercle may be present toward the centre of each ocular. The plates are variably sculptured in different specimens.

The ambulacra are about half the width of the interambulacra with a narrow poriferous tract in which the pore-pairs are uniserially arranged. The primary ambulacral tubercles bordering the poriferous tract form a regular vertical series. In each echinoid triad the pore-pairs are arranged in ill-defined arcs, and usually are separated by well-defined ridges radiating from the primary tubercle. The pores themselves are small and in each pore-pair they are equal in size, with the wall between rising to a rounded elevation. The secondary tubercles are variable in number and arrangement and a bare median zone may be developed adapically.

The interambulacra possess regular vertical series of primary tubercles, similar to, but slightly larger than the corresponding ambulacral tubercles. Usually there is radiating sculpture originating from the boss of the primary tubercle, but this can be almost lost. The secondary tubercles are variable both in number and arrangement; in larger specimens, which possess poorly developed sculpture, they are more numerous and the ambital plates may bear poorly defined horizontal series of slightly enlarged secondary tubercles. The bases of the bosses of the primary tubercles are irregularly scalloped. Bare median zones in which growth ridges of the plates are seen may be developed, particularly adapically.

MEASUREMENTS:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
P17964	8·5 mm	4·7 mm	*c* 2·0 mm	3·3 mm	8	8
P17965	15·5	9·0	4·0	6·0	12(13)	11(12)
P17966	20·0	14·5	6·2	7·5	15	13(14)
P17967	21·0	12·5	6·0	8·0	15(16)	14(15)
P17968	24·2	13·7	7·0	10·0	18	15
P17969	26·5	16·2	7·0	9·2	18	15
AUGD17016	21·0	11·7	6·0	8·0	15	13

ABNORMALITY: One specimen (P17965; Fig. 1a) with a broken apical system, shows one of the three genital plates present to possess two genital pores.

SYNOPSIS OF MATERIAL: From the Morgan Limestone, of Batesfordian and Balcombian age: 'Morgan', P17964-78, P18104; 'River Murray', AUGD17016; '4 miles below Morgan', P18045; 8 specimens *ex* R. J. Foster Coll., various localities in the Morgan Limestone along the Murray River Cliffs.

REMARKS: Fig. 1d-f, i-l and Pl. 3, figs. 1-5, 8-9 illustrate the considerable variation in sculpture and tuberculation which is seen in this species. In general it seems that during growth the very strong radiating sculpture of small specimens is lost to varying degrees and more secondary tubercles are developed. In large specimens bare median zones which extend down to the ambitus may be developed in the ambulacra and interambulacra. Both these features are known in the living genus *Desmechinus*.

The strong radiating sculpture of small specimens compares closely with that seen in *Orthologhus pulchellus* (Bittner) which is also known only from the Morgan Limestone. In small specimens of comparable size, *Cryptechinus humilior* may be distinguished by the fewer and higher plates which possess more prominent and

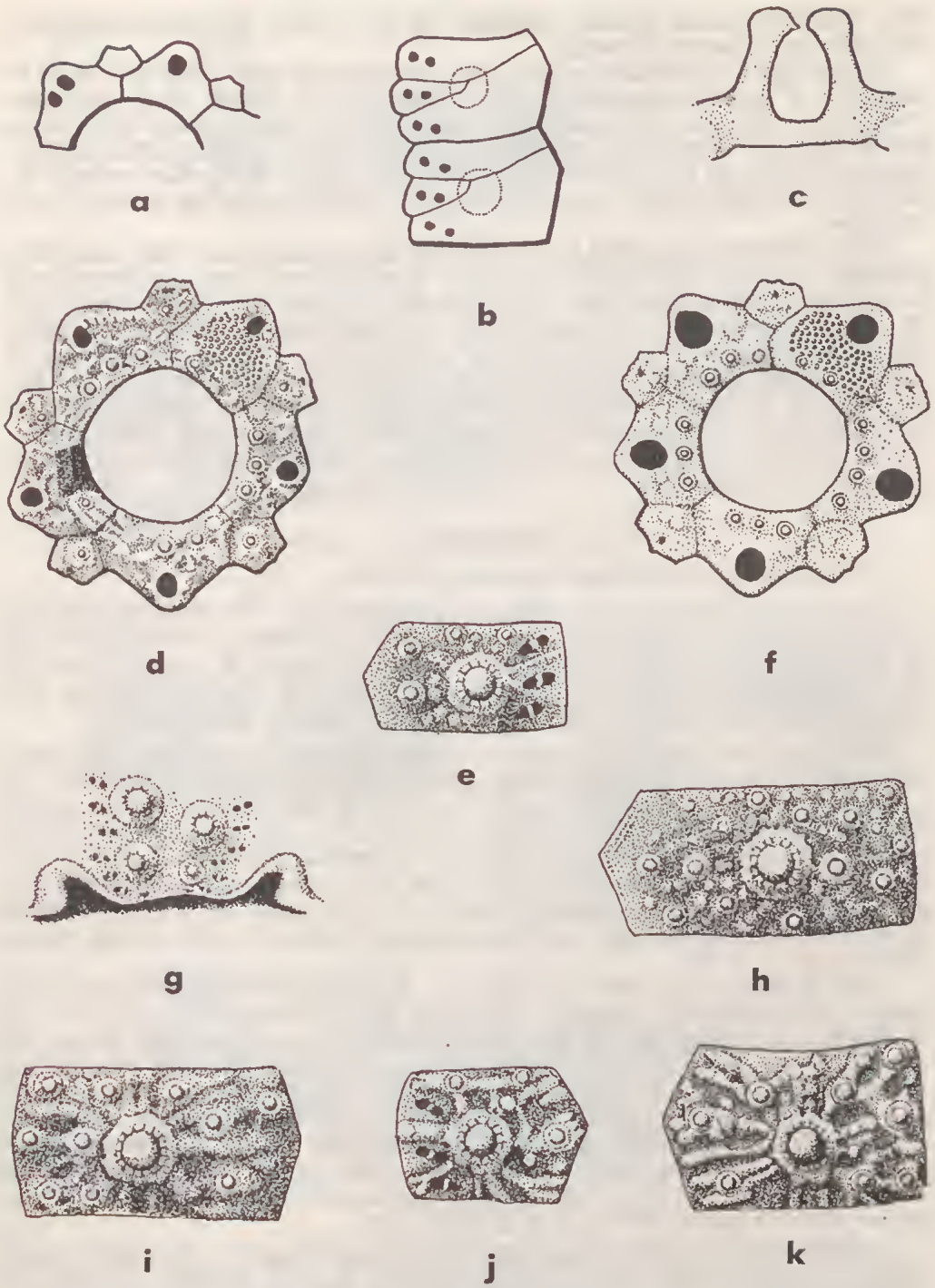

FIG. 1—*Cryptechinus humilior* (Bittner). a, Abnormal apical system with two pores in one genital plate (P17965), × 6. b, Analysis of ambital ambulacral plating (P17968), × 10. c, Auricles (P17971), × 10 approx. d, Apical system of a highly sculptured specimen (AUGD17016), × 6. e, Ambital plate of an obscurely sculptured specimen (P17968), × 10. f, Apical system of highly sculptured specimen (AUGD17016), × 6. g, Adoral termination of an ambulacral column showing the well buttressed gill slits (P17966), × 15. h, Interambulacral plate of an obscurely sculptured specimen (P17968), × 10. i, Interambulacral plate of a moderately sculptured specimen (P17966), × 10. j-k, Ambulacral and interambulacral plate of a highly sculptured specimen (AUGD17016), × 10.

more strongly crenulate primary tubercles, the more open and coarser sculpture and the fewer secondary tubercles.

The excessive enlargement of the genital pores seen in four of the specimens is suggestive of sexual dimorphism similar to that seen in species of *Prionechinus* where the females have enlarged genital pores and the males possess small pores mounted at the extremities of the plates. The dimorphism is well marked in *Prionechinus* whereas in *C. humilior* it could well arise merely from wide variation in the size of the pores—the apparent dimorphism an artefact of the present small collection.

Bittner originally described the tubercles of this species as only very doubtfully perforate. Lambert and Thiéry (*loc. cit.*), however, must have interpreted the description otherwise to list this form as a species of *Echinopsis*. The tubercles lack all trace of perforation. Although Bittner was perplexed by Duncan's (1889) definition of the genus *Psammechinus*, he had a very clear idea of the affinities of this species, for he writes 'Die Oberflächensculptur dieser Art zeigt somit gewisse Anklänge an die Gruppe der Glyphocyphinen, die ja auch sonst, insbesondere im Baue der Ambulacralplattensysteme, den Echininen äusserst nahe steht', an observation which anticipates to a remarkable degree the present-day conception of the family Temnopleuridae.

Genus **Asaphechinus** gen. nov.

TYPE SPECIES: *Asaphechinus murrayensis* sp. nov.

DIAGNOSIS: Usually large sculptured temnopleurids with strongly crenulate tubercles and sharp gill slits. The pore-pairs of the ambulacra are arranged usually in well-marked arcs within each triad. The apical system is regularly dicyclic. Mature individuals are obscurely sculptured, usually with irregular granules. The perignathic girdle consists of high auricles united above the ambulacra.

REMARKS: The strongly crenulate character of the tubercles sets this genus apart from the other sculptured temnopleurids with which it could otherwise be compared (e.g. *Desmechinus*). *Asaphechinus* would seem to have closest affinity with the living genus *Asterechinus* Mortensen 1942. This genus was proposed for a single specimen from the Admiralty Islands. *Asterechinus* posseses strongly crenulate tubercles, arcuate pore-pairs in the triads, and united auricles. However, the gill slits are not sharp, the secondary tubercles are very small, the sculpture consists of peculiar radiating granules, and the margins of the bosses of the primary tubercles are closely serrate.

Thus it can be seen that the Janjukian *A. tasmanensis* sp. nov., the oldest species of *Asaphechinus*, conforms closely to the characters of *Asterechinus*, for it differs only in the absence of the peculiar radiating granules and the sharper gill slits. However, the species of *Asaphechinus* form a morphological series which show progressive specialization in the deepening of the gill slits, the enlargement of the secondary tubercles and loss of serration of the primary tubercles, and an increase in test size, culminating in the Upper Miocene species *A. singletoni*. It is thus considered unlikely that the living *Asterechinus elegans* bears any direct relationship with the Australian Tertiary forms, although conceivably both could have arisen from the same stock in early Tertiary times.

Asaphechinus is to be distinguished from *Cryptechinus* by the arcuate pore-pairs of the triads, the united auricles, and the general character of the more obscure sculpture.

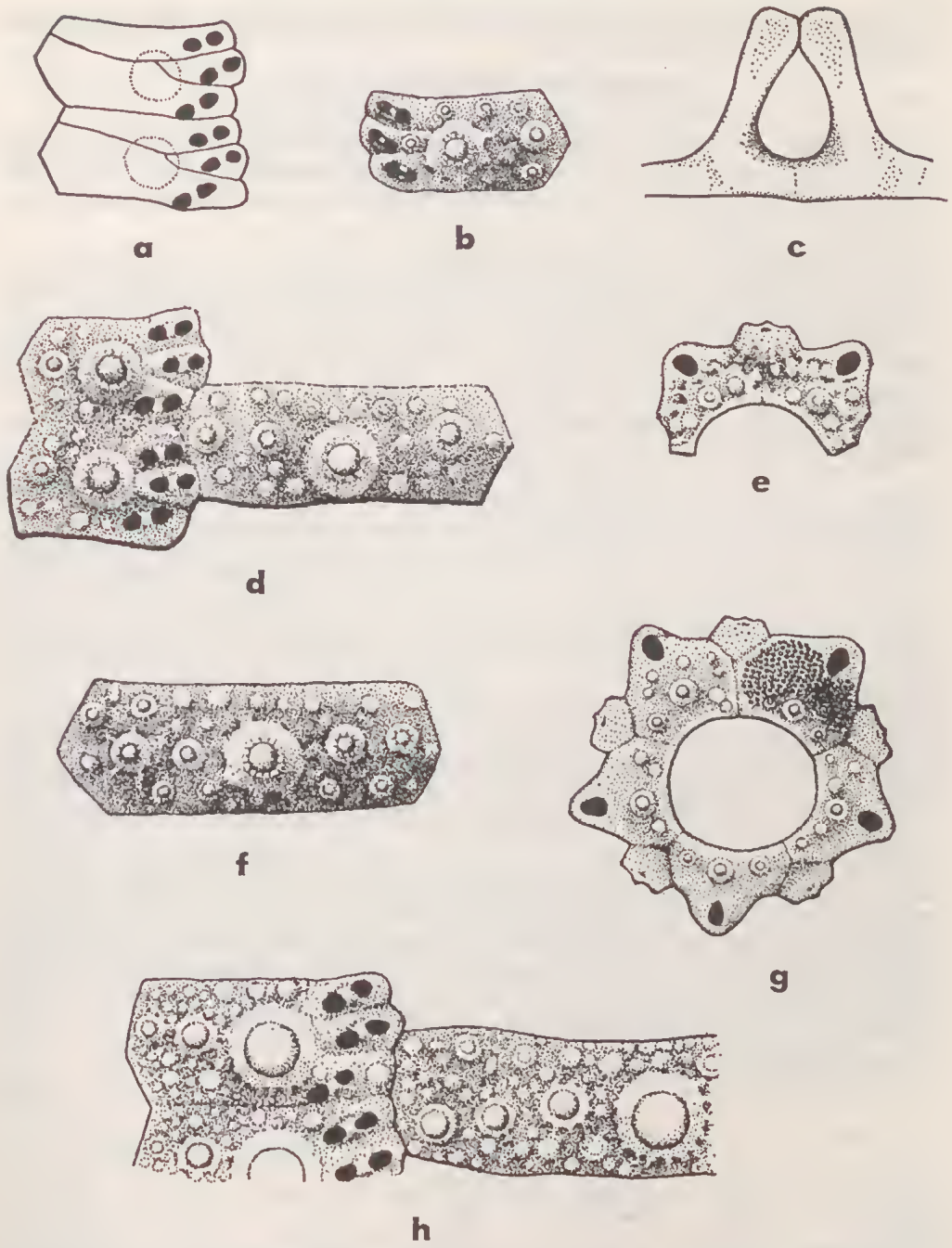

FIG. 2a-c, e-g—*Asaphechinus murrayensis* gen. et sp. nov. a, Analysis of ambulacral plates (P18173), × 10. b, Ambital ambulacral plate of holotype (P18172), × 10. c, Auricles of holotype, × 10. e, Sculptured genital plates in apical system of a small specimen (AUGD17017), × 10. f, Ambital interambulacral plate of holotype, × 10. g, Apical system of holotype, × 6. d, *Pseudechinus* sp. cf. *P. albocinctus* (Hutton). Ambital ambulacral and interambulacral plates (P18367), × 15. h, *Grammechinus meridionalis* sp. nov. Ambital ornament of holotype (P19211), × 10.

The generic name from ασαφης, *indistinct*, refers to the poorly defined sculpture of adult members of the genus.

Asaphechinus murrayensis sp. nov.

(Pl. 5, fig. 1-4, 6-7, 12; Pl. 12, fig. 5, fig. 2a-c, e-g)

DIAGNOSIS: A moderately large species of *Asaphechinus* with incised ambulacra on the adoral surface of adult specimens. The secondary tubercles are not markedly enlarged and the bases of primary tubercles are not strongly scalloped. The apophyses are low.

MATERIAL: Eight tests, 3 with apical systems.

TYPE SPECIMEN: The holotype is P18172, a test from 'lower beds, Murray River Cliffs, Swan Reach to Mannum', Mannum Formation, Longfordian.

DESCRIPTION: The test is low and depressed with a flattened adoral surface which is sunken around the peristome. On the adoral surface the ambulacra are incised in the larger specimens. The gill slits are small, sharp and well-buttressed. The girdle consists of strong high auricles united above the ambulacra, and connected by low apophyses.

The apical system is dicyclic but is distinctly elongate along an axis from genital 3 to ocular 1 which thus tends to be more insert than the other oculars. The madreporite is not enlarged although the raised porous area extends over most of the surface of genital 2. Each of the genitals possesses a comparatively large, centrally located secondary tubercle, and a few smaller secondary tubercles which may form an ill-defined circlet around the periproct. The oculars appear to be devoid of all ornament although a small specimen shows low irregular sculptural ridges running from the genitals to the oculars. The genital pores are rather large and slightly elongate.

The ambulacra are about half the width of the interambulacra, with narrow poriferous tracts in which the pore-pairs in each triad are distinctly, although not markedly, arcuate. The primary ambulacral tubercles are mounted close to the poriferous tracts and form regular vertical series. The secondary tuberculation is irregular but, at the ambitus, a slightly enlarged secondary tubercle may be present inside the primary tubercle.

The interambulacral plates possess rather small median primary tubercles, similar in size to the corresponding ambulacral tubercles. At the ambitus the interambulacral plates are distinctly arcuate and almost geniculate. A horizontal series of slightly enlarged secondary tubercles is present along the middle of each plate. The interambulacra are further ornamented by smaller secondary tubercles and irregular granules between which are often poorly defined pits. The bosses of the strongly crenulate primary tubercles are not markedly scalloped.

MEASUREMENTS:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
P18172	26·2 mm	14·0 mm	6·0 mm	9·2 mm	19	16(17)
P18173	22·5	12·2	5·5	8·5	19	16(17)
P18174	17·5	8·7	4·2	6·2	15	13(14)
AUGD17017	15·2	8·2	4·0	6·0	16	14

SYNOPSIS OF MATERIAL: Mannum Formation, Murray River Cliffs, Longfordian: 'Lower beds, Swan Reach to Mannum', P18172-4; 'Behind and west of

pumping station, 4′ from top of formation' (S.A. Mines Dept. F43/55), AUGD-17017; 'Murray River Cliffs', B.M. E17731; '3 miles N. of Mannum', AUDG17021; 'Mannum, right bank', 2 specimens R. J. Foster Coll.

REMARKS: A comparatively small specimen which shows distinct sculpture, suggests that young specimens may possess well developed sculpture similar to those of *Cryptechinus humilior* (Bittner).

Asaphechinus princeps sp. nov.

(Pl. 5, fig. 8-10; Pl. 12, fig. 5; Pl. 14, fig. 1-3; Fig. 3c, e, g)

DIAGNOSIS: A large thick-tested species of *Asaphechinus* in which the ambulacra of the flattened adoral surface are not incised nor is the test sunken around the peristome. The subambital secondary tubercles are enlarged to be of similar size to the small primary tubercles, so that horizontal series of tubercles are present beneath the ambitus.

MATERIAL: Four tests, one with apical system.

TYPE SPECIMEN: The holotype is AUGD17020, a large test lacking the apical system from '3 miles N. of Mannum, right bank of Murray River', Mannum Formation, Longfordian.

DESCRIPTION: The test is large with a flattened adoral surface which is not sunken around the peristome. The peristome is distinctly notched, with sharp gill slits. The auricles are broken in the available material, but the girdle appears to have been similar to that of *A. murrayensis*.

The apical system is dicyclic, but is poorly preserved in the available specimen. The madreporite is not enlarged and the genital plates appear to have been ornamented with secondary tubercles which form a circlet around the peristome.

The ambulacra are about half the width of the interambulacra and possess wide poriferous tracts in which the pore-pairs are strongly arcuate in each low triad. In each pore-pair the wall between the pores rises to a rounded elevation and the inner pore is larger and more rounded than the outer pore. The primary ambulacral tubercles, which form a regular vertical series, are mounted close to the poriferous tracts leaving a wide median zone in the ambulacra.

The interambulacral plates possess small, centrally placed primary tubercles. Above the ambitus the secondary tubercles are small and irregularly spaced, but at and below the ambitus some of the secondary tubercles are enlarged, and immediately below the ambitus these attain a size similar to the small primary tubercles, so that horizontal series are formed on each plate. The tubercles are strongly crenulate, and the bases of the bosses are markedly scalloped. Apart from the tubercles the surface of the test is marked by irregular granules and low ridges, which impart a peculiar vermiculate appearance to the surface of the test (Pl. 5, fig. 10) particularly adapically. In the interambulacral midzone are distinct growth ridges.

MEASUREMENTS:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
AUGD17021	31·0 mm	17·5 mm	9·0 mm	*c* 11·0 mm	24	16(17)
AUGD17018	35·0	*c* 19·00	—	12·0	—	—
AUGD17020	44·5	28·5	9·5	12·5	29(30)	20

Synopsis of Material: Mannum Formation, Murray River Cliffs, Longfordian: 'Sec. 519, Finnis' (*ex* S.A. Mines Dept. F46/55) AUGD17018; '3 miles N. of Mannum, right bank', AUGD17020-1, and 1 further specimen, R. J. Foster Coll.

Remarks: *Asaphechinus princeps* occurs with *A. murrayensis* in the Mannum Formation. Apart from its larger size, the features by which *A. princeps* may be distinguished are:

1. The lower ambulacral plates.
2. The absence of incised ambulacra on the adoral surface.
3. The peristomial margins are not sunken.
4. The enlargement of the inner pores of each pore-pair.
5. The bases of the bosses of the primary tubercles are strongly scalloped.
6. The relatively smaller primary tubercles and the more sparse secondary tuberculation, particularly of the adipical surface.
7. The enlargement of the subambital secondary interambulacral tubercles.

Features 3 and 4 are not seen in other species of *Asaphechinus*.

A striking character of three of the specimens is the peculiar vermiculate appearance of the surface of the test (Pl. 5, fig. 10; Pl. 14, fig. 2). This, however, appears to be variable, for in the fourth specimen referred to the species (Pl. 12, fig. 5) this ornament is not well developed although the surface detail of this test is, for the most part, obscured.

Asaphechinus singletoni sp. nov.

(Pl. 6, fig. 1-4, 8-12; Pl. 12, fig. 3-4, 7; Pl. 13, fig. 4; Fig. 3a-b, d, f, h-i)

Diagnosis: A large species of *Asaphechinus* with very large secondary interambulacral tubercles on the adoral surface. The apophyses extend as extremely high ridges between the spatulate auricles.

Material: Ten tests, one with apical system.

Type Specimen: The holotype is a large test from the Singleton Collection (593) and is now catalogued as MUGD3490. It is from Beaumaris from the Sandringham Sands of Cheltenhamian age.

Description: The test is large and usually depressed with a rounded outline, and a flattened adoral surface which is slightly concave around the relatively small, sharply notched peristome. The auricles are high and spatulate, and are united above the ambulacra. The apophyses, the peristomial faces of which are furrowed by continuations of the gill slits, form high walls between the auricles.

The apical system is regularly dicyclic with the madreporite not enlarged although the raised porous area extends over most of the surface of genital 2. Each of the genitals possesses a comparatively large, centrally located secondary tubercle, bordered on each side by a further secondary tubercle so that a circlet is formed around the periproct. Each of the ocular plates bears a similar secondary tubercle. All plates bear irregular sculptural ridges. The genital pores are comparatively large and rounded.

The ambulacra are slightly wider than half the width of the interambulacra. The poriferous tracts are comparatively wide as the pore-pairs are distinctly arcuate in each echinoid triad. The primary tubercle of each plate is well separated from the poriferous tract, usually with a small secondary tubercle mounted between it and the median pore-pair of each triad. The pore-pairs in each triad are separated

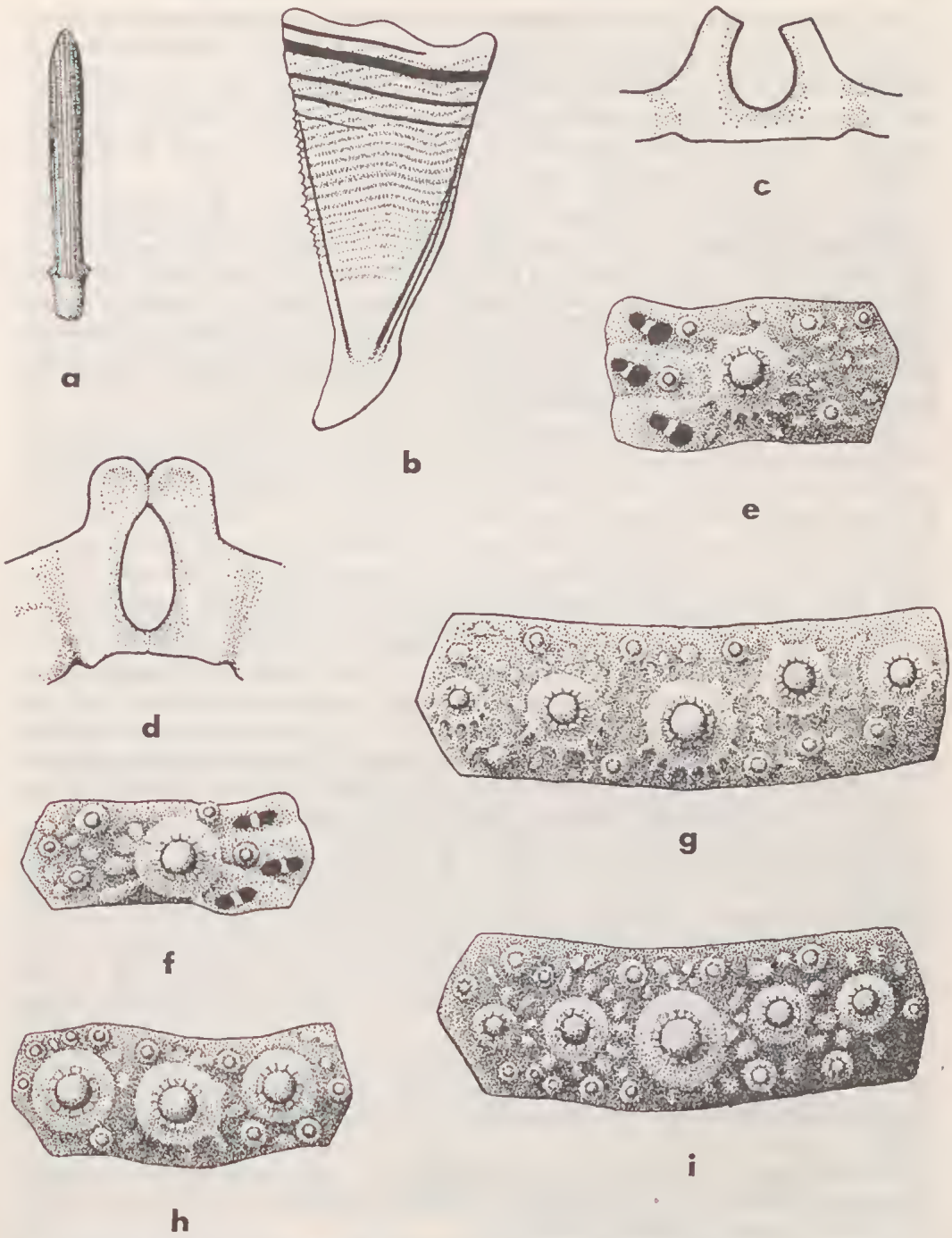

FIG. 3a-b, d, f, h-i—*Asaphechinus singletoni* sp. nov. a, Radiole (MUGD34901), × 10. b, Interpyramidal face of right maxilla, showing growth zones oblique to the sinuous ridges for the attachment of the comminator muscles (MUGD3490B), × 8 approx. d, Auricles (MUGD3490), × 10. f, Ambital ambulacral plate of holotype (MUGD-3490), × 10. h, Subambital interambulacral plate of holotype, × 10. Ambital interambulacral plate of holotype, × 10. c, e, g, *Asaphechinus princeps* sp. nov. c, Broken auricles of holotype (AUGD17018), × 6. e, Ambital ambulacral plate of holotype, × 12 approx. g, Ambital interambulacral plate of holotype, × 12 approx.

by low ridges radiating from the bosses of the primary tubercles. The pores themselves are rounded, with the wall between rising to a distinct elevation which is truncated below by a shallow groove. The secondary tubercles are irregularly arranged, with only one or two on the most adapical plates, while at and immediately below the ambitus an enlarged secondary tubercle is present on each plate inside the primary tubercle. Because the ambulacral plates are low, the primary tubercles are closely spaced in a regular vertical series.

The interambulacral columns possess regular vertical series of crenulate primary tubercles, similar to but slightly larger than those of the corresponding ambulacral plates. Adapically the interambulacral plates are covered with small secondary tubercles. At the ambitus on each plate two of these are slightly enlarged, while immediately below the ambitus they become similar in size to the primary tubercles. Between the secondary tubercles the plates are ornamented by often elongated, somewhat radiating granules, and the base of the bosses of the larger tubercles may be irregularly scalloped. The surface of immature specimens is marked by faint, irregular sculptural depressions (Pl. 13, fig. 4).

Lantern, Etc: During its cleaning the holotype was inadvertently fractured, so the soft matrix within the specimen was completely removed. Parts of the lantern and several radioles were discovered, lodged behind the girdle. Recovered from the matrix within the specimen were (MUGD3490 A-I): 2 maxillae, 2 teeth, 1 rotula (brace), 4 small radioles. Subsequently a further collection of lantern remains removed from P23971 was discovered in the National Museum, Melbourne collections. These include: 5 maxillae, 1 rotula, 3 teeth, 6 epiphyses and 1 compass.

The lantern remains are typically camarodont. The upper surfaces of the maxillae in the second collection are well preserved and show their pitting.

Of interest is the fact that the maxillae show 'growth lines' on the intermaxillial faces. Growth zones are normally seen in all the echinoderm remains from the Mordialloc Beds at Cheltenham; the limonite of the highly ferruginous sediments appears to have permeated the calcite, deeply staining sutures, and often differentially staining different growth zones within the ossicles. In some specimens there has also been differential solution of these growth zones.

For obvious reasons there is no information available concerning the growth of maxillae, but, from general considerations, it would seem likely that the pyramids would grow mainly at their upper ends. This proves to be the case. The later growth increments, at least in the plane of the interpyramidal faces, are mainly transverse with only slight vertical component. The increments cut the low, sinuous ridges which afforded the attachment of the comminator muscles. Together with a great increase in the height of the pyramid there has been only a slight increase in the width of the lower region of the maxilla.

The radioles are all small with a wide base and a prominent milled ring. The somewhat fusiform shaft tapers to a distal point. The acetabulum is poorly preserved on the only specimen which shows the base, so that the crenulation is not visible.

Synopsis of Material: From the Sandringham Sands at Beaumaris, Cheltenhamian: MUGD3490, BME17858-9, P23971, P23989; 'Above nodule bed', P23968-9; 'Loose in shingle', P23982-3.

Remarks: Many of the tubercles of the type specimen have been stripped of their crenulation. Weathering of the specimen, in other respects well preserved,

MEASUREMENTS:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs
P23968	14·5 mm	8·0 mm	*c* 4·5 mm	5·5 mm	15(16)	13(14)
P23969	18·0	9·5	4·0	6·0	15(16)	14
P23982	19·0	9·5	—	7·5	17	15
BME17895	24·0	11·5	*c* 6·0	9·5	18	14(15)
MUGD3490	32·0	16·2	6·0	10·0	23(24)	17(18)
P23971	34·0	24·0	7·0	11·0	29(30)	21(22)

appears to have been initiated around the parapet of the tubercles and in some cases has continued until now most of the boss has been removed, leaving the mamelon on a 'stalk' of the calcite of the central part of the boss. This would seem to indicate that the glossy mamelons are composed of calcite harder than that of the bosses. Other tubercles possess the strong crenulation typical of *Asaphechinus*.

The broad subambital pit in one of the interambulacral areas of the holotype is apparently the work of some boring organism. However there is no evidence to suggest that this is not *post mortem*.

Asaphechinus tasmanensis sp. nov.

(Pl. 6, fig. 5-7; Pl. 15, fig. 2; Fig. 8g-h, j)

DIAGNOSIS: A small species of *Asaphechinus* with shallow gill slits, small primary tubercles and a flattened adoral surface.

MATERIAL: Five tests.

TYPE SPECIMEN: Holotype, P19043, 'Upper bed, Table Cape', i.e. Fossil Bluff Sandstone of Janjukian age.

DESCRIPTION: The test is small and depressed with a flattened adoral surface. The gill slits are small and relatively shallow.

The apical system is distinctly elongate with ocular I more inset than the other oculars. The pores of the madreporite extend over almost all of the surface of genital 2. The genitals are ornamented by three or four secondary tubercles, the central one of which is usually slightly enlarged. The genital pores are rather large and tear-shaped and mounted distally. The short oculars may be obscurely ornamented by occasional granules, as may also be the genitals.

The ambulacra are about half the width of the interambulacra with a comparatively narrow poriferous tract although the pore-pairs of each triad are arcuate. The primary ambulacral tubercles form a regular vertical series, and one or two secondary tubercles and obscure granules are present on each plate.

The interambulacral plates possess rather small, centrally mounted primary tubercles, which form regular vertical series. The small, irregularly placed secondary tubercles form ill-defined horizontal series on the plates toward the ambitus. The obscure sculpture is of irregular ridges, granules and pits, making the surface of the test rough. The primary tubercles are strongly crenulate, and the bases of the bosses are scalloped.

SYNOPSIS OF MATERIAL: The holotype and P19042, P23984-6, all from the type locality.

MEASUREMENTS:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
P23985	20·5 mm	8·0 mm	*c* 5·0 mm	7·5 mm	16	13(14)
P19042	17·8	8·0	5·0	6·0	15	12(13)
P23986	16·5	7·5	4·5	6·5	14(15)	13
P19043	14·0	8·0	4·5	6·0	13(14)	11

REMARKS: The girdle was broken in the specimen it was possible to excavate; however, it appears to have been the same as that of *A. murrayensis*. Indeed, this form is very similar to the small specimens of *A. murrayensis*, and perhaps should be regarded as only a subspecies.

Genus **Grammechinus** Duncan and Sladen

Grammechinus Duncan and Sladen 1885, p. 82.
Grammechinus Duncan and Sladen, Mortensen 1943a, p. 374, (*cum synon.*)
? *Goniosigma* Fell 1964, p. 201.

TYPE SPECIES: *Grammechinus regularis* Duncan and Sladen, by monotypy.

DIAGNOSIS: Comparatively large forms with a somewhat fragile test, flattened on the adoral surface and slightly sunken around the peristome. The tubercles are smooth, and enlarged secondary tubercles form horizontal series in both the ambulacra and interambulacra. The gill slits are distinct and well buttressed. The pore-pairs are arranged in distinct arcs of three.

REMARKS: This genus was proposed by Duncan and Sladen for the adoral portion of a single specimen from the Miocene of Kattywar. Mortensen (*loc. cit.*) considered from the published information that it was impossible to decide whether or not the form represented a temnopleurid. However, as illustrated, the temnopleurid affinities of *Grammechinus* are indicated by the depressions in the horizontal sutures, which are bridged by ill-defined ridges running between the primary tubercles, and also the obscurely radiating granules. The genus thus can be regarded as belonging to the sculptured temnopleurids. The Australian species described below lacks the depressed horizontal sutures of the type species, but its affinities are indicated by the scalloped bosses of the tubercles, and also the presence of obscure pits on the surfaces of the plates. In other respects it would seem to be identical with the Indian species.

There can be little doubt that *Grammechinus* is closely related to, if not identical with, the living genus *Desmechinus* H. L. Clark, but until further information is available, particularly concerning the apical system and auricles of *Grammechinus*, the safest procedure is to leave the genera separate. This may also be said of the genus *Javanechinus* Jeannet, from the Miocene of Java, which was placed in synonymy with *Desmechinus* by Mortensen merely on the basis of the surface ornament (Mortensen *op. cit.*, p. 339). Although Jeannet describes the peristome as notched, the gill slits of *Javanechinus* seem to be far less distinct than those of *Desmechinus* and *Grammechinus* (Jeannet and Lambert 1935). Thus, although the value of these various genera is questionable, from the information which is at present available they cannot be merged safely.

The same must be said of *Goniosigma* Fell 1964, based on *Echinus enysi* Hutton 1873, from the Oligocene of the Trelissic Basin, N.Z. Although regarded as a synonym of *'Psammechinus' woodsi* Laube by Hutton (1887; Tate 1894),

the species has subsequently afforded the record of the genus *Grammechinus* from New Zealand (Hawkins *in* Mortensen 1925; Fell 1953). *Goniosigma* is diagnosed as possessing smooth tubercles and differing from *Grammechinus* in 'having the small secondary tubercles of the interradial (admedian) angles of the interamb plates arranged in vertical zig-zag series, parallel to the adradial sutures . . .' Hutton's original specimen alone was available to Fell in proposing this genus.

In the present study it was found that secondary granules and ridges in the interambulacral midzone aligned parallel to median sutures occur in many Tertiary species (e.g. *Cryptechinus humilior*, Pl. 3, fig. 4; *Asaphechinus murrayensis*, Pl. 5, fig. 6; *Asaphechinus princeps*, Pl. 5, fig. 10). It is apparently an extremely variable growth feature of the test, developed in some large individuals of these species. It cannot be said to be fully characteristic of any of the Australian species. Accordingly it is concluded that *Goniosigma* is based on an evanescent feature of slight taxonomic value. The status of *Goniosigma* must remain in doubt until such time as the nature of the apical system, the character of the ambulacra, the gill slits and the perignathic girdle become known. As the tubercles are described as smooth it does not appear to be synonymous with any of the Australian genera proposed here.

Grammechinus meridionalis sp. nov.

(Pl. 4, fig. 10-13; Pl. 14, fig. 5-6; Fig. 2h)

DIAGNOSIS: A species of *Grammechinus* lacking depressions in the horizontal sutures, but with bosses of the primary tubercles scalloped.

MATERIAL: Seven tests, one with apical system.

TYPE SPECIMEN: Holotype P19211, a laterally compressed test, partly enveloped in limestone matrix, from the 'lower beds, Aldinga'. The matrix indicates that the specimen was derived from the Port Willunga Beds of Janjukian to Batesfordian age.

DESCRIPTION: The test is relatively large and rounded in outline, with a flattened adoral surface which is slightly concave around the peristome. The gill slits, although small, are fairly sharp and well buttressed.

The apical system is regularly dicyclic with the madreporite not enlarged, although the raised, porous area extends over most of genital 2. The surface is poorly preserved, but a circlet of secondary tubercles around the peristome is visible on the genital plates.

The ambulacra are about half the width of the interambulacra, with a fairly wide poriferous tract. The primary ambulacral tubercles form a regular series close to the poriferous tract, leaving a wide median ambulacral zone. Within each triad the pore-pairs are strongly arcuate and are separated by ill-defined ridges radiating from the base of the boss of the primary tubercle. The pores are round and well separated in each pair, with the wall between rising to a well marked elevation. On each plate an enlarged secondary tubercle is present inside the primary tubercle so that a horizontal series is present on each plate.

The interambulacral columns possess regular vertical series of median primary tubercles, similar in size to the corresponding ambulacral tubercles. A horizontal series of up to six secondary tubercles may be present on each interambulacral plate at the ambitus. As with the ambulacra, the rest of the surface of the test is ornamented with smaller secondary tubercles and irregular granules among which are small shallow pits. The tubercles are smooth with narrow parapets which are overhung by the large, almost spherical mamelons. The bases of the bosses are irregularly scalloped.

MEASUREMENTS:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
AUGD17024	37·0 mm	15·0 mm	10·5 mm	12·0 mm	24	18
P19211	35·0	20·0	—	12·0	25	20
P20213	29·0	16·0	7·0	9·5	19(20)	15

SYNOPSIS OF MATERIAL: AUGD17024-5, and 3 other tests, R. J. Foster Coll. 'Whitton Bluff', Blanche Point Marl, Upper Eocene; P19211, P20213, 'low beds, Aldinga', Port Willunga Beds, Janjukian to Batesfordian.

REMARKS: Cursory examination of this species immediately suggests a comparison with *Asaphechinus* which contains large forms with buttressed gill slits and arcuate pore-pairs. However, the smooth tubercles of *Grammechinus meridionalis* indicate no close relationship here. Furthermore, the arcuate triads of *Grammechinus* are different from those seen in *Asaphechinus*. In the present species the primary ambulacral tubercles are mounted adjacent to the poriferous tract, and the lower pore-pair is inwardly displaced beneath the primary tubercle. A small secondary tubercle is usually present outside the pore-pair of the lowermost component of each triad. In *Asaphechinus* the primary ambulacral tubercle is well separated from the poriferous tract, and a small primary tubercle is generally mounted between the median component of each triad and the primary tubercle.

G. meridionalis differs from *G. regularis* Duncan and Sladen in the smaller gill slits and the absence of depressed horizontal sutures. The scalloping of the bosses of the primary tubercles, as seen in *G. meridionalis*, is not shown in Duncan and Sladen's (1885; Pl. 13, fig. 8) enlargement of the surface detail of their species.

Genus **Orthologhus** Duncan

Orthologhus Duncan 1887, p. 414.
Orthologhus Duncan 1889, p. 100.
Coptechinus Cotteau, Bittner 1892, p. 339 (*partim*).
Paradoxechinus Laube, Tate 1892, p. 191 (*partim*).
Prionechinus A. Agassiz, Lambert and Thiéry 1910, p. 230 (*partim*).
Paradoxechinus Laube, Mortensen 1943a, p. 350 *et seq.* (*partim*).
Pseudechinus Mortensen, H. L. Clark 1946, p. 323 (*partim*).
Brochopleurus Fourtau, Fell 1949, p. 17 *et seq.* (*partim*).
Irenechinus Fell 1964b, p. 211 *et seq.*; Fell 1964a, p. 202; Fell and Pawson 1966, p. 423.
Paradoxechinus Laube, Fell and Pawson 1966, p. U424 (*partim*).

TYPE SPECIES: *Temnechinus lineatus* Duncan, by monotypy. The type species of *Irenechinus* Fell is *I. hentyi* Fell (= *Coptechinus pulchellus* Bittner, *fide* Philip 1966) by original designation.

DIAGNOSIS: Moderate sized, sculptured temnopleurids with faintly crenulate tubercles, uniserial ambulacra and obscure gill slits. The apical system is regularly dicyclic. Juveniles are strongly sculptured, the sculptural ridges being lost with growth to varying degrees in different species, the obscurely sculptured forms being closely tuberculated. The girdle consists of rather low auricles, with or without capping (Hawkins 1934, p. 622), united above the ambulacra.

REMARKS: Much of the past uncertainty as to the application of this genus stems from Duncan's original description of the type species, the discrepancies in which were originally pointed out by Bittner (1892). Duncan gave his genus as

sculptured by a net-work of 'ridge-like costae', but his figure of the type specimen of *O. lineatus* shows no trace of sculpture. The above diagnosis has been expanded to cover the several different species here included in the genus.

Together with *Coptechinus*, from the Tertiary of Europe, *Orthlophus* has long been considered a synonym of *Paradoxechinus*. *Coptechinus* differs in possessing smooth tubercles and has secondary ornament of granules rather than tubercles. *Paradoxechinus* (q.v.) is characterized by the sexual dimorphism of the test.

A review of the past confusion of Australian Tertiary species of *Orthlophus* (with crenulate tubercles) and the Indian and Egyptian Miocene genus *Brochopleurus* (with smooth tubercles) and the resultant erection of *Irenechinus* Fell, has been given elsewhere (Philip 1966).

Two species groups can be distinguished in the Australian Tertiary forms here referred to *Orthlophus*. These are:

1. *O. bittneri—O. morganensis—O. venustus* group in which mature specimens are strongly sculptured.
2. *O. woodsi—O. pulchellus—O. lineatus* group in which the highly developed sculpture of juveniles is lost, or becomes much less obvious during growth.

Some gradation between the groups is seen in species *O. lineatus* and *O. venustus*, but extremes (such as *O. pulchellus* and *O. morganensis*, which occur together in the Morgan Limestone) are so dissimilar in their appearance, that their reference to the one genus might be questioned. However, the differences are based on distinctions in the sculpture, and no fundamental characters permit separation of the species.

The known stratigraphic ranges of the various species in the Australian Tertiary are given in Fig. 4.

Outside of the Tertiary of SE. Australia *Orthlophus* occurs in the Oligocene of New Zealand, for *Irenechinus minor* Fell (1964a, p. 202-203; Pl. 2, figs. 3-4) is clearly referrable to *Orthlophus*. The species apparently belongs to the *woodsi-*

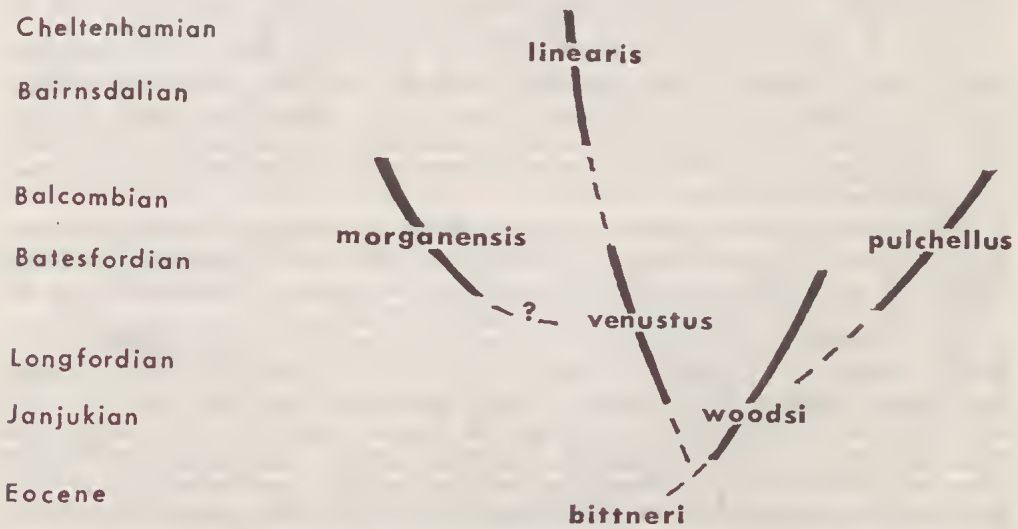

FIG. 4—Stratigraphic and possible phylogenetic relationship of the Australian Tertiary species of *Orthlophus*.

pulchellus species group, but, as it is based on a single immature specimen, little more can be added concerning its relationship to the Australian species.

Orthologhus lineatus (Duncan)

(Pl. 7, fig. 14-18; Pl. 9, fig. 10; Pl. 12, fig. 6; Fig. 5g, i)

Temnechinus lineatus Duncan 1877, p. 46; Pl. 3, figs. 3-5.
Orthlolophus lineatus (Duncan), Duncan 1887, p. 413-414; Duncan 1889, p. 101; Tate 1891, p. 274.
Paradoxechinus novus Laube, Tate 1892, p. 191-192 (*partim*).
Prionechinus lineatus (Duncan), Lambert and Thiéry 1910, p. 230.
Paradoxechinus novus Laube, H. L. Clark 1946, p. 308 (*partim*).
(*Non*) *Paradoxechinus novus* Laube 1869, p. 188, fig. 2.
(*Nec*) *Orthlolophus lineatus* (Duncan), *sensu* Bittner 1892, p. 338. *et seq.*
(*Nec*) *Coptechinus lineatus* Bittner, *loc. cit.*
(*Nec*) *Paradoxechinus lineatus* (Duncan), Mortensen 1943a, p. 351, fig. 210b-c.

Diagnosis: A species of *Orthlolophus* with coarsely sculptured early growth stages which give rise to adults with poorly defined sculptural ridges and rather distant secondary tubercles.

Material: Five poorly preserved tests lacking apical systems.

Type Specimen: The holotype is that specimen originally figured by Duncan from 'Mordialloc, No. 1'. It is a worn and imperfect test, but the surface ornament is retained on one side. The matrix is of a buff-coloured limestone, so presumably the specimen was from a nodule from within the Mordialloc Beds. The specimen, originally in the Geological Society of London Collections, is now catalogued as BM GSL14078.

Description: The test is of moderate size, with a rounded outline and a slightly flattened adoral surface. The peristome is small and the gill slits obscure. The perignathic girdle is known in only one immature specimen where it consists of low uncapped auricles united above the ambulacra and connected by relatively high apophyses. The ambulacra are relatively wide, about three quarters of the width of the interambulacra. The pore-pairs are uniserial and arranged in very weak arcs in each echinoid triad. The primary ambulacral tubercles are mounted close to the poriferous tracts, and two low ridges, radiating from the primary tubercle, separate the pore-pairs in each triad. At the ambitus the primary tubercle is joined on each plate by a slightly enlarged secondary tubercle in the wide median ambulacral zone. Adorally the ambulacral plates tend to be crowded and the pore-pairs there are reduced in size.

The interambulacra possess a regular series of primary tubercles mounted slightly adradially in each column. Toward the ambitus each interambulacral plate possesses a horizontal series of slightly enlarged secondary tubercles, two on the median side of the primary tubercle and one adradially.

The primary tubercles, which form regular vertical series, are imperforate and faintly crenulate. The surface of the test is covered by small secondary tubercles and elongate granules which tend to radiate from the primary tubercle giving the impression of vertical ridges connecting the primary tubercles. The base of the boss of the primary tubercles may be scalloped by these. Irregular pits and depressions occur on the surface of the plates between the ridges and secondary tubercles. In immature specimens double sculptural ridges bearing secondary tubercles zig-zag across the ambulacral and interambulacral midzones, but this pattern is obscured during growth.

MEASUREMENTS:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
BMGSL14078	15·0 mm	9·0 mm	*c* 3·5 mm	5·0 mm	14	13
BME17857	12·5	6·5	*c* 4·0	5·5	11(12)	10(11)
P23981	8·5	5·0	—	3·5	11	10

SYNOPSIS OF MATERIAL: 'Orbost', i.e. equivalents of the Bairnsdalian Bairnsdale Limestone, P18431. From the Cheltenhamian Sandringham Sands: Holotype; P23988, BME17857, 'Beaumaris', P23981 'Loose in shingle'.

REMARKS: In its sculpture this form appears to be intermediate between *O. woodsi* and *O. venustus*. The holotype is to be distinguished from *O. woodsi* by the more sparse secondary ornament, and the persistence of vague sculptural ridges in what is apparently a mature specimen. The sculpture of immature specimens is similar to that of *O. venustus*.

Orthologhus bittneri nom. nov.

(Pl. 11, fig. 13-21; Pl. 13, fig. 2-3, 5-7; Fig. 6c, e, i-j)

Coptechinus lineatus Bittner 1892, p. 338-341; Pl. 1, fig. 4.
Paradoxechinus novus Laube, Tate 1892, p. 191-192 (*partim*).
Paradoxechinus lineatus (Bittner), Lambert and Thiéry 1910, p. 230.
Paradoxechinus lineatus (Duncan), Mortensen 1942a, p. 351, fig. 210b (*partim*), c, d (*partim*).
Paradoxechinus novus Laube, Fell and Pawson 1966, fig. 317 (1a), (*non*) 1b.
(*Non*) *Temnechinus lineatus* Duncan 1877, p. 46; Pl. 3, fig. 3-5.
= *Orthologhus lineatus* (Duncan), Duncan 1887, p. 413-414.
(*Nec*) *Paradoxechinus novus* Laube 1869, p. 188, fig. 2.

DIAGNOSIS: A species of *Orthologhus* with a somewhat pentagonal outline and strongly developed zig-zag sculptural ridges. The apical system has a small porous area and the genital pores are small and slit-like.

MATERIAL: Forty-four tests, many with apical systems.

TYPE SPECIMEN: Of Bittner's three original specimens, that illustrated in his Pl. 1, fig. 4 is here chosen as lectotype. The specimen is lost (I, p. 183). Bittner notes that his specimens 'sind grünlich gefärbt' which suggests that they were derived from the Tortachilla Limestone. As neotype P20488 is here selected. This test is from the Tortachilla Limestone, and conforms closely with the lectotype.

DESCRIPTION: The test is somewhat pentagonal in outline and possesses flattened adoral and adapical surfaces. The peristome is small and the gill slits are obscure. The girdle consists of relatively wide, spatulate auricles united above the ambulacra, and connected by narrow apophyses.

The apical system is small and dicyclic, with the posterior oculars slightly more insert than the anterior. The madreporite is not enlarged and the porous area is small. The genital pores are small and may be slit-like. The plates are covered with irregular sculptural ridges and irregular granules of which the series bordering the periproct are the best defined. The ambulacra are about half of the width of the interambulacra, and possess narrow poriferous tracts in which the pores are uniserial or obscurely arcuate in each echinoid triad. The pore-pairs are small and tend to be sunken in the 'epistroma' surrounding the primary ambulacral tubercles which form regular vertical series close to the poriferous tracts.

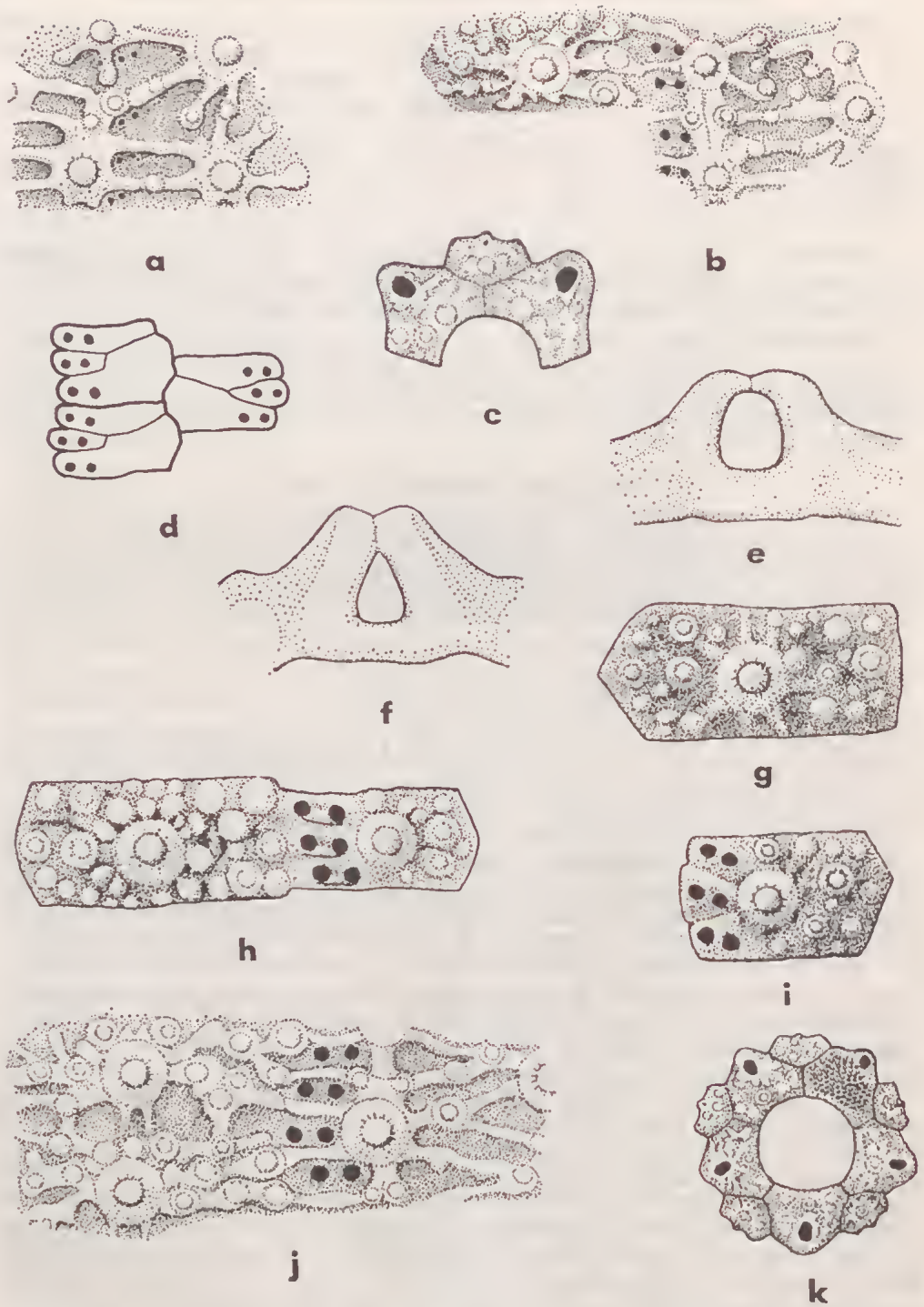

FIG. 5—a-e, h, *Orthologhus woodsi* (Laube). a, Ambital sculpture of a very small specimen (P18331), × 25. b, Ambital sculpture of a moderately large specimen (P18332), × 15 approx. c, Portion of apical system of a small specimen showing sculpture (P18269), × 15. d, Analysis of ambulacral plating (P18177), × 10. e, Auricles (P18268), × 10. h, Ambital plates of a large specimen (P18176), × 15. f, j-k, *Orthologhus pulchellus* (Bittner). f, Auricles (P17987), × 10. j, Ambital sculpture of a large specimen (P17983), × 15. k, Apical system (P17980), × 10. g, i, *Orthologhus lineatus* (Duncan). g, Ambital interambulacral plate of holotype (BM, GSL14078), × 15. i, Ambital ambulacral plate of holotype, × 15.

The interambulacra have a similar vertical series of imperforate, faintly crenulate, primary tubercles. The secondary ornament consists of prominent raised tuberculate ridges connecting the primary tubercles in each vertical series, and zigzagging between the primary tubercles in each zone. From each primary interambulacral tubercle several ridges are present running adradially across the primary ambulacral tubercles between pore-pairs. The sculpture varies considerably in its detail (Pl. 13, fig. 2-3, 5-7).

MEASUREMENTS:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
P19237	10·5 mm	7·0 mm	3·5 mm	3·5 mm	13	12
P20489	10·0	6·0	3·5	—	12	11
P20488	12·5	8·0	4·0	4·5	12	11

SYNOPSIS OF MATERIAL: Upper Eocene Tortachilla Limestone, 'Aldinga': P20488-90; P19237-8; P20223-4; P19213; P20473-4; UNE10565-9 and 29 other specimens R. J. Foster Coll.

REMARKS: The sculpture of the test of this species recalls to a remarkable degree that seen in the species *Dictyopleurus ziczaz* and *Dictyopleurus haimei* Duncan and Sladen (1882; Pl. 9, figs. 1-5), from the Eocene and Sind, but no close relationship between Australian and Indian forms can be suggested for *Dictyopleurus* is a glyphocyphid. The range of variation seen in the sculpture of *O. bittneri* is considerably greater than that illustrated by Duncan and Sladen as distinguishing their two species.

Because of the contradiction between Duncan's figures and description of his *Orthologhus lineatus*, Bittner was unable to decide whether this species was different from Duncan's species. In view of this (and also because of his uncertainty as to the generic placement of the species) he attributed the authorship of *Coptechinus lineatus* to himself, thus creating a primary homonym, which is corrected above.

Orthologhus morganensis sp. nov.

(Pl. 7, fig. 1-13; Fig. 6a-b, h)

Paradoxechinus novus Laube, Tate 1892, p. 191-192 (*partim*).
(*Non*) *Paradoxechinus novus* Laube 1869, p. 188, fig. 2.

DIAGNOSIS: A large, strongly sculptured species of *Orthologhus* with high sculptural ridges. The interambulacral midzones are slightly sunken. The auricles are capped.

MATERIAL: Twenty-six tests, several with apical systems.

TYPE SPECIMEN: Holotype P17997, from the mid-Miocene Morgan Limestone at Morgan.

DESCRIPTION: The test is rather large and high with a flattened adoral surface which may be slightly concave around the peristome. On the larger specimens the interambulacral midzones are depressed. The gill slits are obscure and the girdle is of delicate capped auricles united above the ambulacra and connected by low apophyses.

The apical system is regularly dicyclic, usually with rounded genital pores

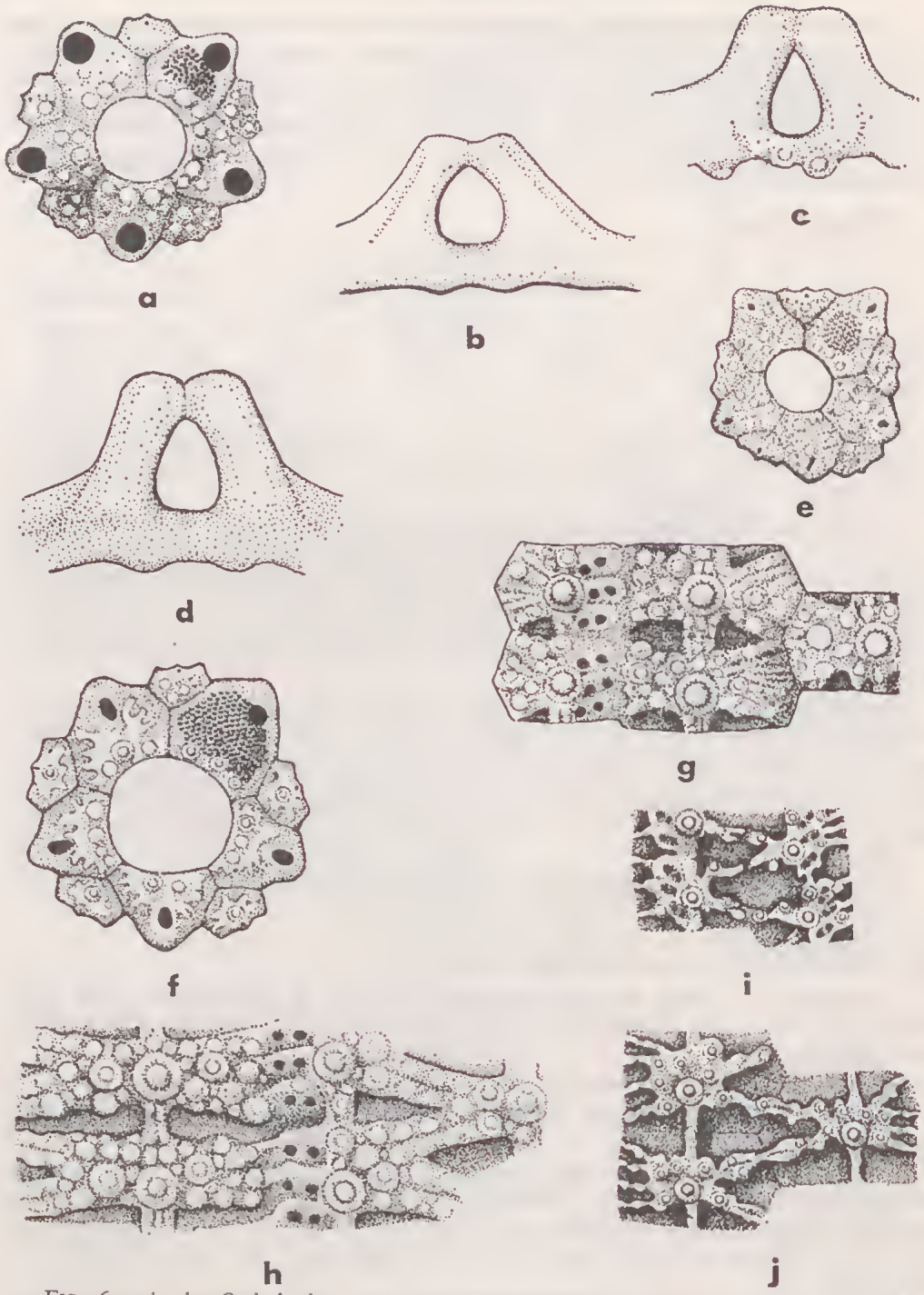

FIG. 6—a-b, h, *Orthologhus morganensis* sp. nov. a, Apical system of holotype (P17997), × 6. b, Auricles (P18002), × 10. Ambital sculpture (P17998), × 10. c, e, i-j, *Orthologhus bittneri* nom. nov. c, Auricles (P20473), × 10. e, Apical system (P20488), × 10. i-j, Ambital ambulacral and interambulacral sculpture of same specimen, × 10. d, f-g, *Orthologhus venustus* sp. nov. d, Auricles (MUGD3493), × 15. f, Apical system (P20124), × 12. g, Ambital ambulacral and interambulacral plates (P20124), × 12.

which are markedly enlarged in one specimen. The madreporite is not noticeably enlarged. The genitals bear a series of secondary tubercles and granules which border the periproct, and are obscurely sculptured. The oculars are closely ornamented with secondary tubercles and granules.

The ambulacra are about three quarters of the width of the interambulaera and possess narrow poriferous tracts in which the pore-pairs are uniserial. The pore-pairs tend to be separated by high, transverse sculptural ridges. The primary tubercles form regular vertieal series adjacent to the poriferous tracts.

The interambulacra also possess regular vertieal series of faintly crenulate primary tubereles, which, in larger specimens, are to the adradial side of the columns, leaving wide median interambulacral zones.

The seulpture is of very thick ridges, whieh are usually coalesced to form wide, coarsely tubereulated bands zig-zagging between the primary tubercles of each ambulacral and interambulaeral zone; similar broad bands run vertically between the primary tubercles of eaeh column.

MEASUREMENTS:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
P17998	18·5 mm	13·0 mm	5·0 mm	6·5 mm	14(15)	16
P17997	16·5	11·5	5·5	5·5	14	14(15)
P18000	15·0	10·5	5·0	5·5	14	14
P17999	14·0	8·5	4·0	5·0	12(13)	13(14)
P18001	9·0	5·0	3·0	3·5	10	9(10)

SYNOPSIS OF MATERIAL: P17997-18015, 'Morgan', Morgan Limestone of Batesfordian or Balcombian age. One specimen in AUGD collections from 'Murray River Cliffs', and 7 specimens R. J. Foster Coll. from localities in the Morgan Limestone.

REMARKS: This form is undoubtedly closely allied to *O. venustus*, but may be distinguished by the larger size, the mueh coarser sculpture, the more highly ornate apical system, and the depressed interambulacral midzones.

Orthologhus pulchellus (Bittner)

(Pl. 10, fig. 1-14; Pl. 15, fig. 1; Fig. 5f, j-k)

Coptechinus pulchellus Bittner 1892, p. 342-344; Pl. 1, fig. 6.
Psammechinus woodsi Laube, Tate 1892, p. 191 (*partim*).
Arbacina pulchella (Bittner), Lambert and Thiéry 1910, p. 231.
Paradoxechinus pulchellus (Bittner), Mortensen 1943a, p. 351, fig. 210b, d. (*partim*).
Progonechinus pulchellus (Bittner), Mortensen *op. cit.*, p. 367.
Pseudechinus woodsi (Laube), H. L. Clark 1946, p. 323-324 (*partim*).
Irenechinus hentyi Fell 1954b, p. 211-213; Pl. 1; Fell and Pawson 1966, fig. 315(5) (inverted).
Orthologhus pulchellus (Bittner), Philip 1966, p. 116.

DIAGNOSIS: A low moderate sized speeies of *Orthologhus* with delicate sculpture whieh persists on quite large individuals; bare depressed areas are developed along the horizontal sutures. The aurieles are eapped.

MATERIAL: Twenty-two tests, 6 with apical systems.

TYPE SPECIMEN: Bittner based this species on three specimens which are now lost. As lectotype the specimen illustrated in his Pl. 1, fig. 5 is here ehosen. The lectotype is lost. Although Bittner's description and figures leave little doubt as to

the identity of the speeies, to avoid subsequent confusion it is necessary for a neotype to be chosen. Aecordingly P17983 is so designated. It is from the Morgan Limestonc (certainly the type formation) at Morgan, of Batesfordian or Balcombian age. The holotype of *Irenechinus hentyi* is P16409 from the Batesfordian Boehara Limestone.

Description: The test is moderately large and depressed with a flattened adoral surfaee. The peristome is small and the gill slits obseure. The auricles meet above the ambulaera and are connected by well developed apophyses.

The apical system in small specimens is regularly dicyelie, with irregular tuberculation and weakly defined sculptural ridgcs. In larger speeimens the plates arc ornamented with closely spaeed secondary tubercles and granules which eover the oeulars and the proximal portion of the genitals; oeular I may be insert (Pl. 15, fig. 1). The genital pores may be slightly ovate and are relatively large.

The ambulaera are about two thirds of the width of the interambulacra. The poriferous tract is narrow, and the pore-pairs are uniserial, although in larger specimens there is a tendency for a secondary tuberele to be mounted outside the pore-pair of the lowermost eomponent of the ambital ambulacral platcs, so that the lowermost pore-pair is inwardly displaced. The primary ambulacral tubercles form regular vertieal scries.

The interambulacra possess regular series of faintly crenulate, imperforate tubercles. Thc secondary tubercles and granules are small and closely spaeed, and tcnd to be mounted on sculptural ridges even in apparently mature specimens. The horizontal sutures are naked and depressed in all but the smallest speeimens. These depressions may be crossed by two or three thread-like ridges arising from thc bosses of the upper tubereles.

Measurements:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
P17979	5·5 mm	3·5 mm	2·5 mm	3·0 mm	8	9
P17980	7·5	5·0	2·5	3·5	9	10
P17981	8·5	5·0	2·5	4·0	10	10(11)
P17982	10·5	6·0	3·5	4·5	11	11(12)
P17985	12·0	7·0	3·0	4·5	12	12(13)
P17983	12·0	7·0	3·5	5·0	13(14)	13(14)
P17984	14·0	8·0	3·5	5·0	14	15
P17986	14·0	8·0	4·5	5·5	13(14)	14
P17931	17·0	11·0	4·5	5·5	14	15

Synopsis of Material: From the Morgan Limestone of Batesfordian or Balcombian age: 'Morgan', P17979-96, AUGD17027 (*ex* R. J. Foster Coll.); 'Overland Corner', P17931, and three specimens *ex* R. J. Foster Coll.

Remarks: The beautiful radiating seulpture of this species persists to quite advaneed growth stages, so that it is seen far more often than in *O. woodsi*. However, in extremely large speeimens, with inerease in the secondary tubereles, pits between the tubercles may be all that remains of the seulpture on the plates. However, the bare depressions along the interambulaeral sutures are a eonstant feature of the species and serve to distinguish *O. pulchellus* from typical speeimens of *O. woodsi*. It must be noted, however, that several specimens in the eolleetion from

the Mannum Formation possess sculpture approaching that of *O. pulchellus* (e.g., Pl. 15, fig. 5). For the present these are referred to *O. woodsi*, but it is possible that they represent forms transitional between the two species. Closely controlled stratigraphic collecting of these species from the strata along the Murray River Cliffs will be necessary before their distribution and relationship is properly understood. The available material suggests that *O. woodsi* is confined to the Mannum Formation and is replaced by *O. pulchellus* in the overlying Morgan Limestone.

Philip (1966) has indicated that *Irenechinus hentyi* Fell must be regarded as a subjective synonym of *O. pulchellus*. Indeed, the synonymy of this species shows a remarkable lack of agreement concerning the generic position of this species. For nine authors there are eight generic locations.

Orthologhus venustus sp. nov.

(Pl. 9, fig. 1-7, 9, 11-14; Fig. 6d, f-g)

DIAGNOSIS: A small species of *Orthologhus* in which adult specimens are sculptured by zig-zagged coalescent ridges, leaving triangular depressions along the horizontal sutures. The aurieles are uncapped.

MATERIAL: Seventeen tests, four with apical systems, and many test fragments.

TYPE SPECIMEN: The holotype is MUGD3492, a test from Brock's Quarry, Glencoe, from the Gippsland Limestone of Batesfordian age.

DESCRIPTION: The test is of moderate size, with a slightly flattened adoral surface. The gill slits are obscure. The girdle consists of rather high delicate aurieles, lacking capping, which just meet above the ambulacra.

The apical system is regularly dicyclic, and is only slightly sculptured. The genital pores are slightly tear-shaped. On the genitals, the secondary tubercles, granules and obscure sculpture are confined to a zone encircling the periproct, leaving bare the extremities of the genitals. Each of the oculars bears a slightly enlarged secondary tubercle, and may be obscurely sculptured.

The ambulacra are about three quarters of the width of the interambulacra. The poriferous tracts, in which the pore-pairs are uniserial, are narrow, and the regular series of primary ambulacral tubercles are mounted close to these.

The interambulacra also possess a regular vertical series of primary tubercles. Adapically, bare unornamented zones along the median interambulacral sutures are variably developed.

The sculpture is of coarse, high ridges, which persist in fully grown specimens. Double or triple ridges zig-zag between the primary tubercles of both the interambulacral and ambulacral zones, and two or three similar ridges, crossing the bare horizontal sutures, tend to connect the primary tubercles in each column. The variation in sculpture is illustrated in Pl. 9, fig. 9, 11-14.

MEASUREMENTS:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
P20124	13·5 mm	9·0 mm	3·5 mm	5	12	13
MUGD3492	11·7	7·0	3·0	4	11	11(12)

SYNOPSIS OF MATERIAL: P20124, 'Longford', Longford Limestone, Longfordian. P18745-58, 'Mouth of Spring Creek', *'Scutellina'* Limestone, Longfordian. From the Gippsland Limestone of Batesfordian age: MUGD3492-3, Brock's

Quarry, Glencoe. GSV57425 (5 test fragments), 'Marl pit 250 yds W. of Brocks'. GSV57429 (4 test fragments); GSV57428 (2 tests and 2 test fragments), 'Le Grand's quarry, Glencoe'.

REMARKS: The only reasonably preserved specimen from the *'Scutellina'* Limestone in the Torquay sequence differs slightly from the Gippsland specimens in the character of the sculpture, particularly in the less strongly developed bare areas along the horizontal sutures, and the poorly defined sculptural ridges. It thus approaches more closely the *O. woodsi* type of ornament. Should this specimen prove fully typical of the *'Scutellina'* Limestone form, then this could be separated as a subspecies of *O. venustus*.

Orthologhus woodsi (Laube)

(Pl. 8, fig. 1-16; Pl. 12, fig. 2; Pl. 13, fig. 1; Pl. 14, fig. 4; Pl. 15, fig. 3, 5; Fig. 5a-e, h)

?? *Echinus* Sturt 1834; Pl. 3, fig. 11.
Psammechinus Woodsi Laube 1869, p. 185-186, fig. 1-1b.
Psammechinus Woodsi Laube, Etheridge 1875, p. 447; Pl. 11, fig. 10-10a; Duncan 1877, p. 64.
Arbacina Woodsi (Laube), Pomel 1883, p. 85.
Psammechinus Woodsi Laube, Duncan 1887, p. 413; Tate 1891, p. 274; Bittner 1892, p. 334-336; Pl. 1, fig. 1-2.
Psammechinus Woodsi var. *fascigar* Bittner, *loc. cit.*
Psammechinus Woodsi Laube, Tate 1892, p. 191 (*partim*).
Prionechinus Woodsi (Laube), Lambert and Thiéry 1910, p. 230.
? *Psammechinus woodsi* Laube, Chapman 1914, p. 145, fig. 80B.
Pseudechinus woodsi (Laube), H. L. Clark 1946, p. 323-324 (*partim*).
Brochopleurus australiae Fell 1949, p. 18-19; Pl. 1 (*partim*).
Orthologhus woodsi (Laube), Philip 1966, p. 116.

DIAGNOSIS: A large species of *Orthologhus*, often with a high test, and finely sculptured early growth stages which give rise to closely tuberculated adults, lacking sculpture. The auricles are uncapped.

MATERIAL: Two hundred and forty tests, many with apical systems.

TYPE SPECIMEN: The holotype is that specimen originally figured by Laube and is now in the Naturhistorisches Museum, Vienna, where it bears the registration number 9019. It is a high, large test, undoubtedly collected from the Mannum Formation, in which the species occurs in profusion. The holotype of *Brochopleurus australiae* Fell is P4687, again from the Mannum Formation.

DESCRIPTION: The test is moderately large, with a flattened adoral surface, and varies in shape from depressed to subconical. The peristome is small, and the gill slits are obscure. The auricles are low and uncapped, but are united above the ambulacra, and are connected by relatively high apophyses.

The apical system is usually regularly dicyclic, with genital 2 not enlarged, although the madreporic pores may extend over most of its surface. In some specimens (e.g. Pl. 15, fig. 3) ocular I is insert. The genital pores are rather large, and may be somewhat tear-shaped. In the more subconical specimens the periproct is rimmed by the upwardly inflected inner margins of the genitals. In early growth stages the apical system may be strongly sculptured, but, with growth, this gives way to closely spaced secondary tubercles and granules.

The ambulacra are from one to two thirds of the width of the interambulacra. In large specimens the ambulacra may be slightly raised, so in outline the test may become subpentagonal. The poriferous tract is narrow, with the pore-pairs uniserial, or arranged in obscure arcs in each echinoid triad. The primary ambulacral tubercles form regular vertical series very close to the poriferous tracts.

The interambulacra possess regular vertical series of imperforate, faintly crenu-

late primary tubercles. Elsewhere the surface of the test of mature specimens is ornamented by closely and irregularly placed secondary tubercles and granules between which are irregular depressions and pits.

MEASUREMENTS:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
P18331	4·5 mm	2·5 mm	1·5 mm	2·0 mm	5	7
P18332	6·0	3·0	—	3·0	7	8
P18333	6·5	3·5	2·0	2·5	8(9)	10
P18270	8·0	4·5	2·5	3·0	10(11)	11
P18271	12·0	7·0	4·0	4·5	11(12)	13(14)
P18176	14·0	10·5	4·5	5·0	17	15
P18177	14·0	10·0	4·5	5·0	15(16)	16
P18178	14·0	12·0	4·0	4·5	16(17)	15
P18179	19·5	16·5	*c* 6·0	*c* 6·0	19(20)	16(17)
P18180	20·0	14·0	6·0	6·5	18	15(16)
NHV9019	22·5	16·5	5·0	5·5	19(20)	16(17)

SYNOPSIS OF MATERIAL: From the Mannum Formation of Longfordian age: 'Mannum', 17 specimens in AUGD Coll. 'Lower Beds between Mannum and Wongulla', P18331-40; 'Wongulla', P18244, P18268-80; 'Swan Reach, P18176-92, P18234-5, R. J. Foster Coll.: 'Mannum', 43 specimens; 'Left bank, 1½ miles N. of Nildottie', AUGD17023 and 19 other specimens; 'Swan Reach', 48 specimens; Mannum pumping station, AUGD17030; 'Cliff above river road just N. of gate to same', AUGD17028 and one other specimen; 'Kroehe's landing', 10 specimens.

From the Torquay sequence: 'Aircy's Inlet', Pt. Addis Limestone, Janjukian, P18832-5 (worn specimens); 'Polyzoal limestone, beach N. of Bird Rock', i.e. '*Cellepora* Limestone', Zeally Limestone, Longfordian, P18586-90; 'Pt. Danger (? Pt. Danger Clay, Batesfordian), P18609-10.

P18609-10, P19161, Gambier Limestone at Nelson, ? Longfordian. GSV57433 'Par Glencoe, allot. 36', Batesfordian. GSV57428, 'Le Grand's Quarry, Glencoe', Gippsland Limestone, Batesfordian. 'Levi's Creek, near Stonefield', Mt. Lofty Ranges, 6 specimens R. J. Foster Coll.

REMARKS: Most remarkable is the change in the character of the sculpture which took place during the growth of the test of this species; indeed, a small, more highly sculptured specimen was named as a separate species by Fell (1949).

The early growth stages possess a strongly developed system of ridges bearing secondary tubercles and radiating from the primary tubercles; these are gradually lost with increase in size and number of the secondary tubercles and so give way to the close secondary granulation of the adult, in which generally no vestige of the sculptural ridges remains. The bosses of the primary tubercles may, however, be slightly scalloped in the adults. The depressions between the secondary tubercles (often seen in temnopleurids) on the surface of the plates apparently arises from the incomplete closure of the original spaces between the ridges. This introduces the possibility that the phenomenon of loss of sculpture during growth (seen in many of the Australian Tertiary species) may obtain in all of the sculptured temnopleurids which have pits on the plates.

Besides variation in sculpture there is also considerable variation in the height of the test. Bittner proposed the variety *fascigar* for the more depressed forms, the holotype possessing a reasonably high test. This variety could be retained, for no

other species of *Orthalophus* shows this variation in shape of the test. It may be noted that Ikeda (1931) maintained that in *Temnopleurus toreumaticus*, which also shows considerable variation in the height of the test, this was due to sexual dimorphism and that the higher tested forms were males. Mortensen (1943a, p. 79), however, was unable to uphold this finding.

In some of the specimens from the Mannum Formation adapically the secondary ornament may be confined to the centres of the plates so that bare interambulacral midzones may be developed (Pl. 14, fig. 4).

The material from the Torquay sequence is unsatisfactory for it contains but few well preserved specimens. Most of the specimens from the *Cellepora* Limestone are indistinguishable from their contemporaries from the Murray River Cliffs. However, one specimen in particular shows considerable enlargement of the secondary tubercles (Pl. 8, fig. 12) and further specimens show a tendency to this feature. It would seem likely, therefore, that the Torquay form may differ slightly from the Murray River Cliffs form, but separation cannot be justified in the available material.

One specimen from Pt. Danger (P18609; Pl. 8, fig. 16) retains what are probably traces of the original coloration of the test. The test is dull purple brown, whereas the mamelons and bosses of the primary and secondary tubercles are creamy white.

The relationship of *O. woodsi* and *O. pulchellus* is discussed under the latter species.

Orthalophus spp. indet.

A number of worn, immature specimens is present in the collection, from localities whence otherwise the genus is not known. They all belong to the *woodsi* species group. The specimens are:
P20099-100, and several specimens in the writer's collection, from the Flinders Limestone at Flinders. P18436, and several specimens in the writer's collection, from the Batesford Limestone at Batesford. P19174-5, P19177, and several specimens in the AUGD collections, from various localities in the Gambier Limestone.

Genus **Paradoxechinus** Laube

Paradoxechinus Laube 1869, p. 186.
Paradoxechinus Laube, Pomel 1883, p. 86.
Paradoxechinus Laube, Duncan 1889, p. 101 (*partim*).
Paradoxechinus Laube, Bittner 1892, p. 339.
Paradoxechinus Laube, Tate 1892, p. 191 (*partim*).
Paradoxechinus Laube, Lambert and Thiéry 1910, p. 230 (*partim*); 1925, p. 570 (*partim*).
Paradoxechinus Laube, Morley Davies 1936, p. 77 (*partim*).
Paradoxechinus Laube, Mortensen 1943a, p. 350 (*partim*).
Paradoxechinus Laube, H. L. Clark 1946, p. 308 (*partim*).
Paradoxechinus Laube, Fell and Pawson 1966, p. U424 (*partim*).

Type Species: *Paradoxechinus novus* Laube, by monotypy.

Diagnosis: Small, depressed forms usually with very prominent sculptural ridges bearing secondary tubercles and granules and zig-zagging between the primary tubercles. The pore-pairs are uniserial and are embedded in the raised 'epistroma' neighbouring the primary ambulacral tubercles. The primary tubercles are crenulate and the gill slits very shallow. The perignathic girdle consists of relatively large spatulate auricles united above the ambulacra and connected by low apophyses. Apical system unknown; sexual dimorphism notably developed, with the females possessing a wide, deep adapical depression.

REMARKS: Because of the uncertainty as to the limits of the species of Australian Tertiary temnopleurids, this endemic genus has been expanded to include many different forms. Duncan (1887, 1889) considered the European genus *Coptechinus* Cotteau to be a synonym of *Paradoxechinus*. Tate (*loc. cit.*) also submerged *Ortholophus* Duncan in *Paradoxechinus*. Lambert and Thiéry (*loc. cit.*) followed Duncan, and subsequently regarded *Brochopleurus* Fourtau as a synonym of *Paradoxechinus*. Mortensen regarded *Brochopleurus* as a separate genus, but placed both *Ortholophus* and *Coptechinus* in the synonymy of *Paradoxechinus*, which also appears to have been the intention of H. L. Clark. Fell and Pawson (*loc. cit.*) follow Mortensen's usage.

All the above mentioned genera are here regarded as discrete (see discussion of *Ortholophus*). The notable feature of *Paradoxechinus* which distinguishes it from other temnopleurids is the character of the sexual dimorphism of the test.

It will be noted that the recent diagnosis of *Paradoxechinus* given by Fell and Pawson (1966) is apparently based largely on *Coptechinus bardini* Cotteau (1883, p. 27; Pl. 4, fig. 3-5) the type species of *Coptechinus*. Hence the tubercles are given as smooth, and it is said that there are no distinct secondary tubercles. The statement that the apical system is regularly dicyclic derives from the species *Coptechinus lineatus* Bittner (*non Ortholophus lineatus* Duncan) (= *Ortholophus bittneri* Philip) which was included in the genus.

Paradoxechinus novus Laube

(Pl. 11, fig. 1-12; Pl. 12, fig. 1; Fig. 7)

Paradoxechinus novus Laube 1869, p. 188, fig. 2.
Paradoxechinus novus Laube, Etheridge 1875, p. 449; Duncan 1877, p. 65; Etheridge 1878, p. 142; Duncan 1887, p. 415.
Paradoxechinus novus Laube, Tate 1891, p. 274 (*partim*).
Paradoxechinus novus Laube, Bittner 1892, p. 344-345; Pl. 4, fig. 4.
Paradoxechinus novus Laube, Tate 1892, p. 192-193 (*partim*).
Paradoxechinus novus Laube, Lambert and Thiéry 1910, p. 230, Mortensen 1943a, pp. 350-351, fig. 210a.
Paradoxechinus novus Laube, H. L. Clark 1946, p. 308 (*partim*).
Brochopleurus australiae Fell 1949, p. 18-19; Pl. 1, (*partim*).
Paradoxechinus novus Laube, Fell and Pawson 1966, fig. 317(1b), (*non*) 1a = *Ortholophus bittneri* Philip.

DIAGNOSIS: As for genus.

MATERIAL: Twenty-three tests, eleven with apical depressions.

TYPE SPECIMEN: The holotype is the specimen originally figured by Laube and is catalogued in the collections of the Naturhistorisches Museum, Vienna, as 9024. The specimen, from the 'Murray cliffs', undoubtedly came from the Mannum Formation of Longfordian age, whence only the species is known to occur.

DESCRIPTION: The test is very low and depressed with a flattened adoral surface which may be slightly concave around the relatively wide peristome. The gill slits are almost wanting. The girdle consists of relatively wide, spatulate auricles united above the ambulacra, and connected by narrow apophyses. A wide adapical depression (described in detail below) is present in some of the specimens.

The ambulacra are about two thirds the width of the interambulacra, with a narrow poriferous tract in which the pore-pairs are arranged in obscure arcs. The primary ambulacral tubercles form regular vertical series close to the poriferous tracts. Typically the pore-pairs are sunken in the raised sculptural 'epistroma' adjacent to the primary tubercles, and so they appear to be conjugate.

The interambulacra possess regular vertical series of primary tubercles mounted

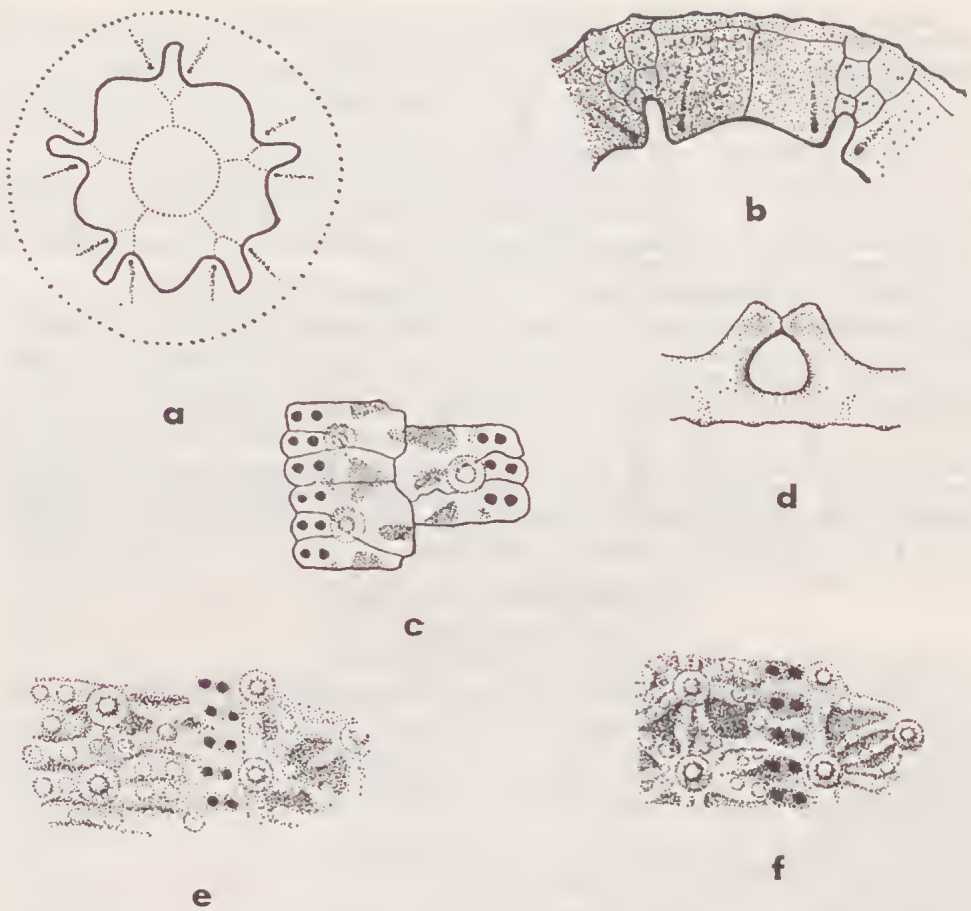

FIG. 7—*Paradoxechinus novus* Laube. a, Outline of margins of the adapical depression with possible plating of a dicyclic apical system (P18243 ♀), × 6. b, Oblique view of plating and ornament within the apical depression (P18243 ♀), × 10. c, Analysis of ambulacral plating (P18223 ♂), × 10. d, Auricles (P18243), × 10. e, Ambital sculpture (P18224 ♂), × 10. f, Ambital sculpture (P18243 ♀), × 10.

toward the centre of each column. Typically the sculpture consists of two irregular strands zig-zagging between the primary tubercles and vertical strands connecting the primary tubercles in each column. The ambulacral midzone is similarly ornamented, and ridges run from the adradial side of the primary ambulacral tubercles to connect with the primary interambulacral tubercles. There is considerable variation in the detail of the sculpture and the ridges may be wide and close, or even merge in smaller specimens. The primary tubercles are faintly, but distinctly, crenulate.

SEXUAL DIMORPHISM: The holotype, and ten other specimens in the present collection, show the remarkable apical depression which has been interpreted by Bittner and Mortensen as a marsupium. None of these specimens show any of the plates of the apical system.

The internal diameter of the depression is from half to two thirds of the diameter of the test and becomes relatively wider during growth. The depression is deep (up to half the height of the test) and sharply bounded by the sudden inflexion of the coronal plates at its borders. The portion of the corona within the depression is slightly concave.

The sculpture and primary tubercles of the test cease abruptly at the margin of the depression and are replaced by granules which become smaller and more distant toward the apical system. In the interradii there are two large interambulacral plates within the depression, while radially there are high, simple ambulacral plates each of which is pierced by a very small pore-pair. At the rim of the depression, these 'immature' ambulacral plates abruptly give way to normal echinoid compound plates. At the apex of each of the interambulacral places within the depression (i.e. to each side of the inferred positions of the oculars) are small pits which do not penetrate to the inside of the test. A shallow groove runs from each of these pits to well up the side of the depression. The inner margins of the depression suggest that the oculars were very elongate (particularly in smaller specimens) and that the apical system was dicyclic.

There can be no doubt that the apical depression of *P. novus* has been correctly interpreted as a marsupium in which the female carried the young. Not only can no other explanation be suggested, but also now specimens have been recognized which do not possess such depressions (i.e. males).

Among sea urchins, brooding of the young is known principally among the cidarids and spatangoids (where the young are carried in the sunken petaloid ambulacra), particularly Antarctic forms. With the sole exception of *Austrocidaris canaliculata* (Agassiz), which bears its young on the apical system, brooding cidarids carry their off-spring around the peristome, protected by the adoral primary radioles. In the other regular echinoids undoubted brooding appears to have been reported only to the Arctic temnopleurid *Hypsiechinus coronatus*, although Gregory (1892b) interpreted the adapical sutural depressions of the British Pliocene species *Temnochinus excavatus* Forbes as 'marsupial pouches' and gave a similar explanation to some obscure adapical interambulacral depressions in *'Echinus' henslovi* Forbes. The same explanation has been given of similar, although better developed adapical depressions in the Cretaceous phymosomatid *Thylechinus said* (Peron and Gauthier) (cf. Mortensen 1935, p. 468, fig. 267a).

The structure of the females of *Paradoxechinus novus* finds its closest analogue in that of the living temnopleurid *Hypsiechinus coronatus*. Here the females possess a prominently elevated apical system in which the plates are strongly inflected to form a distinctive knob. The young are carried around this knob on the adapical surface of the test. The most interesting similarity with the condition of *Paradoxechinus novus* is that the upper interambulacral plates (on which the young are perched) are remarkably high and have lost their primary tubercles, these latter being replaced by small granules (Mortensen 1943a, p. 295, fig. 161). Furthermore, Mortensen's (1943a, p. 45, fig. 42) drawing of the ambulacral structure of *Hypsiechinus coronatus* shows the upper plates to be of simple primaries—presumably similar to those of *P. novus*.

In the females of both *P. novus* and *H. coronatus* the high upper interambulacral plates would seem to afford a barrier preventing the introduction of the new interambulacral plates, so that the number of plates in adult females would remain constant from the onset of sexual maturity and the beginning of the formation of the marsupium. This can be seen from the table of measurements given below; in the males the number of plates increases continually with growth, whereas in the

females, after the formation of the marsupium, increase in the size of the corona is achieved solely by increase in the size of the coronal plates. It follows, then, that in mature specimens of comparable size, the plates of the female are relatively higher.

No explanation can be suggested for the pits toward the margins of the enlarged adapical interambulacral plates.

MEASUREMENTS:

Females:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.*	No. interambs.*
P18243	9·5 mm	4·5 mm	4·5 mm	3·7 mm	7(8)	8(9)
P18266	10·5	5·0	5·2	4·0	7	8(9)
P18175	13·0	6·2	—	*c* 4·5	7(8)	8(9)

* Outside apical depression.

Males:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
P18267	8·0 mm	4·5 mm	*c* 2·5 mm	3·0 mm	7	8
P18222	9·0	4·5	*c* 2·0	3·0	8	10
P18223	11·5	5·5	3·0	4·0	9	10

SYNOPSIS OF MATERIAL: From the Mannum Formation of Longfordian age: 'Lower beds, Swan Reach to Mannum', P18222-5; P18175; 'Wongulla, above Mannum' P18243, P18266-7; 'Left bank, 1½ miles N. of Nildottie', 11 specimens R. J. Foster Coll.; 'Mannum', 2 specimens R. J. Foster Coll.

REMARKS: Some difficulty may be found in distinguishing small specimens of the males of this species from immature specimens of its associate *Ortholophus woodsi*, for the wide variation in the character of the sculpture of *P. novus* can approach that of the small forms of this latter species. Indeed, Fell (1949) in describing an immature specimen of *Ortholophus woodsi* as *Brochopleurus australiae*, included a second specimen in his species which is here interpreted as a male form of *P. novus* (P4688). However, in *O. woodsi* the secondary ornament is much finer, the test is seldom as low, the ambulacra are narrower and there are more coronal plates.

Genus **Pseudechinus** Mortensen

Pseudechinus Mortensen 1903, p. 106.
Pseudechinus Mortensen 1943a, p. 223 *et seq.* (*cum synon*).
Pseudechinus Mortensen, H. L. Clark 1946, p. 323 (*partim*).
Pseudechinus Mortensen, Fell 1958, p. 35; 1960, p. 71.

TYPE SPECIES: *Echinus albocinctus* Hutton by monotypy. Lambert and Thiéry (1914, p. 243) give *Echinus magellanicus* Philippi as the type species but this species is not mentioned by Mortensen in the founding of the genus.

DIAGNOSIS: Small or moderate sized, thin tested forms, usually somewhat hemispherical in shape. The pore-pairs of the ambulacra arranged in distinct arcs of

three. The apical system is dicyclic or has the posterior oculars insert. Primary tubercles usually large, and crenulate to varying degrees. The gill slits are shallow. Sculpture is usually completely lacking in adult specimens.

REMARKS: H. L. Clark (*op. cit.*) included the genus *Pseudechinus* in the family Echinidae, although the crenulation of the tubercles in some species speaks strongly against this association. Mortensen, on the basis of the pedicellariae, regarded the genus as a temnopleurid within the subfamily Temnopleurinae. More recently Fell (1958) has found some confirmation of this position for, in describing a new species, *P. flemingi*, he noted the occurrence of 'weak radial sculpture' traces of which were also observed in young specimens of *P. albocinctus* and *P. novaezealandae*.

It is possible that *Pseudechinus* was derived from the older Australian Tertiary temnopleurids, but a number of peculiarities seem to preclude its direct descent from the present-known species. The general appearance of the test, especially the absence of well defined sculpture in mature individuals, recalls the condition of *Asaphechinus*, particularly the early species *A. tasmanensis*. The rather strongly crenulate tubercles of the Miocene representative of *Pseudechinus* described below, would also support such ancestry. But the later species of *Asaphechinus* are larger, more specialized forms, particularly in the character of the gill slits (and, indeed, deepening of the gill slits appears to be progressively developed through the succession of species of *Asaphechinus*).

Another possible ancestor is the genus *Orthologhus* (the range of which *Pseudechinus* overlaps in time). With the loss of sculpture and with the development of areuate pore-pairs in the ambulaeral triads, *Orthologhus* could have given rise to *Pseudechinus* (H. L. Clark 1946, actually regarded the species *Orthologhus woodsi* (Laube) as a species of *Pseudechinus*). However, the rather strongly crenulate tubercles of the Miocene *Pseudechinus* sp. cf. *P. albocinctus* does not support such ancestry.

DISTRIBUTION: Mortensen (1943a) recognized nine species and one variety. Subsequently Fell (1958) described a further species. Some of these forms are based on one or two, probably immature specimens, and so are of doubtful value. Species groups which may be recognized are:

1. *Pseudechinus albocinctus* (Hutton) from New Zealand, with the allopatric forms *P. magellanicus* (Philippi) from S. America and *P. marionensis* Mortensen from the Marion Islands. The recently described *P. flemingi* Fell from the Chatham Islands also appears to be a form closely related to, and allopatric with *P. albocinctus*.

2. *Pseudechinus novaezealandiae* (Mortensen) from southern New Zealand.

3. *Pseudechinus huttoni* Benham [and its probable synonym *P. grossularia* (Studer)], with the allopatric Australian forms *P. notius* (H. L. Clark) and *P. hesperus* H. L. Clark. *P. variagatus* Mortensen would seem to be a further allopatric New Zealand form of this species.

Within New Zealand waters the living species groups appear to be sympatric.

The fossil form *Echinus andinus* Philippi, of uncertain age from Chile (*fide* Mortensen 1943a, p. 226, fig. 199) and included by Lambert and Thiéry (1914) in the genus *Pseudechinus*, would seem to have far too prominent gill slits to be placed here.

H. L. Clark (1946) included the Australian Longfordian species *'Psammechinus' woodsi* Laube in the genus, but this is a species of *Orthologhus* (*q.v.*).

Fell (1953) suggests that the genus probably appeared in the Australian Plio-

cene and records it from 'corresponding sediments' in New Zealand. Subsequently, in describing his *P. flemingi* (1958, p. 36), he noted that it occurred in 'Castlecliffian (Pleistocene) sediments near Wanganui'. It would seem, therefore, that *P. flemingi* is the form identified by Farquhar (1894, p. 196) and de Loriol (1904, p. 20) as *Echinus albocinctus* Hutton. Farquhar gives the occurrence as from the 'Pliocene formation at Shakespeare Cliff, Wanganui' and de Loriol 'Landguard Bluff près Wanganui'.

The upper Miocene form described below is apparently the oldest known species of *Pseudechinus*.

Pseudechinus albocinctus (Hutton)

Echinus albocinctus Hutton 1873, p. 12.
Pseudechinus albocinctus (Hutton), Mortensen 1943a, p. 227-232; Pl. 47, figs. 25, 31 (*cum synon*).

Pseudechinus sp. cf. **P. albocinctus** (Hutton)

(Pl. 9, fig. 8, 15; Fig. 2d)

DIAGNOSIS: A form apparently identical with *P. albocinctus* but with smaller primary tubercles and more strongly crenulate tubercles.

MATERIAL: One broken test (P18367) partially freed from matrix, from 'Toorloo Creek, Toorloo Arm of Lake Tyers', i.e., equivalents of the Bairnsdale Limestone of Bairnsdalian age.

MEASUREMENTS:

h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
15·7 mm	9·5 mm	4·5 mm	—	16	12

REMARKS: This single, imperfect specimen seems to resemble very closely the living New Zealand species with which it is at present compared. Its measurements are remarkably similar to those of the smallest specimen in Mortensen's (1943a, p. 228) table of measurements of *P. albocinctus*. It differs from the Recent species in the less arcuate pore-pairs of the ambulacra and the smaller and more strongly crenulate primary tubercles. Should further material establish these distinctions, then the Australian Upper Miocene form should be separated from the living species.

Genus **Tatechinus** gen. nov.

TYPE SPECIES: *Tatechinus nudus* sp. nov.

DIAGNOSIS: Medium sized sculptured temnopleurids with strongly crenulate tubercles, the adoral margins of the bosses of which are scalloped. The sculpture is confined to a few elongate granules toward the centres of the adoral plates, and also on the plates of the apical system. Bare median areas extending below the ambitus are present in the ambulacra and interambulacra, and adapically the tuberculation of the interambulacra is confined to the central portion of the plates. The auricles are united above the ambulacra, and the gill slits are poorly defined.

REMARKS: Although the bare median areas of the ambulacra and interambulacra are seen in temnopleurids in such genera as *Microcyphus*, *Salmacis* and *Mespilia*, this is their first occurrence in the group of sculptured temnopleurids.

Thus *Tatechinus* stands well apart from other genera of the family. The strong crenulation of the tubercles also serves to distinguish the genus, and thus allies it with *Cryptechinus* and *Asaphechinus*.

The genus is known only from the single Upper Eocene species. As bare unornamented zones of the test are elsewhere regarded as a specialization, it is surprising to find them developed in this early representative of the family.

In the living temnopleurid *Mespilia* Desor, Mortensen (1943a, p. 176-177) notes that the bare zones of the ambulacra and interambulacra are marked by 'whitish spots' made conspicuous by the 'whitish colour on the dark ground colour of the plate'. These radiate from the centre of the plate. Mortensen further adds that 'the whitish colour seems to be due to a structural difference, the calcareous network being more open in the whitish spots and stripes than in the rest of the test'. This condition is similarly manifest in the bare zones of the test of *Tatechinus*, although here the fibres tend to cross the sutures at right angles. However, rather than the condition arising from a 'more open network', it would seem to result from a regular preferred orientation of the fibres parallel to the surface of the plates within the bare zone; elsewhere in the plates (as normally) the calcareous mesh-work is more or less irregular, the orientation of fibres being apparently normal to the surface of the plates.

The genus is named for Professor Ralph Tate, whose contributions to Australian Tertiary palaeontology prior to the turn of the century did much to elucidate the character of the whole fauna.

Tatechinus nudus sp. nov.

(Pl. 4, fig. 7-9, 14-15; Pl. 14, fig. 7; Pl. 15, fig. 4; Fig. 8a-f, i)

Psammechinus Woodsi Laube, Tate 1892, p. 191 (*partim*).
(*Non*) *Psammechinus Woodsi* Laube 1869, p. 185-186, fig. 1-1b.

DIAGNOSIS: As for genus.

MATERIAL: Thirty-five tests, several of which retain apical systems.

TYPE SPECIMEN: Holotype P20212, a large test from 'lower beds, Aldinga', Tortachilla Limestone, Upper Eocene.

DESCRIPTION: The test is moderately large and subconical with a slightly flattened adoral surface which may be slightly concave around the peristome. The peristome is comparatively small. The gill slits are poorly defined. The perignathic girdle consists of strong, flattened auricles united above the ambulacra and connected by rather high apophyses.

The apical system is regularly dicyclic with pores of the madreporite covering most of genital 2. The genitals are ornamented by one to three secondary tubercles and irregular granules which also may be present on the oculars. The genital pores are fairly large and may be somewhat tear-shaped.

The ambulacra are slightly less than half the width of the interambulacra and possess narrow poriferous tracts in which the pore-pairs of each triad are arranged in obscure arcs. The ambulacral plates are very high, particularly adapically. Within the pore-pairs the pores are rather large and rounded, with the wall between rising to a well marked elevation. The primary ambulacral tubercles form regular vertical series close to the poriferous tract, leaving the conspicuous bare median zone of the ambulacra which extends down below the ambitus. The secondary ornament of the plates possesses but a few secondary tubercles and granules. The granules extend from the ornamented portion of each plate onto the poriferous tract.

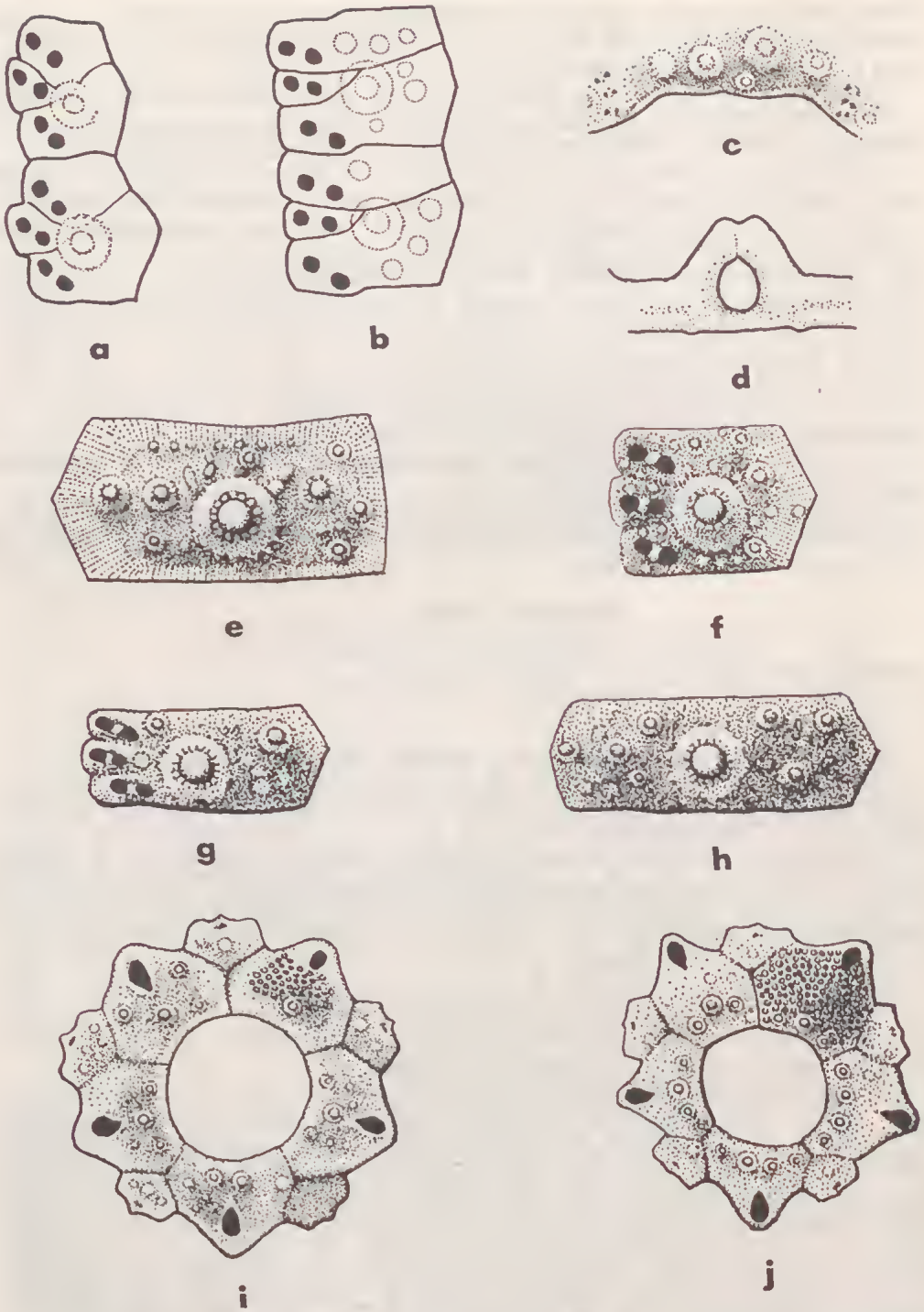

FIG. 8—a-f, i, *Tatechinus nudus* gen. et sp. nov. a, Analysis of ambital ambulacral plating of holotype (P20212), × 10. b, Adapical ambulacral plating of holotype, × 10. c, Peristomial margin showing poorly developed gill slits (P20212), × 10. d, Auricles (P19239), × 8. e, Ambital interambulacral plate of holotype, × 10. f, Ambital ambulacral plate of holotype, × 10. i, Apical system of holotype, × 6. g-h, j, *Asaphechinus tasmanensis* gen. et sp. nov. g, Ambital ambulacral plate of holotype (P19042), × 12. h, Ambital interambulacral plate of holotype, × 12. j, Apical system of holotype, × 8.

Like the ambulacra, the interambulacral plates are high, and possess small primary tubercles which form regular series toward the adradial side of each column, leaving bare the conspicuous median area of the interambulacral midzone. In the plates at and above the ambitus the ornament is confined to the middle part of each plate, so that the horizontal sutures also lie in naked areas, and a narrow naked area is also present adradially. Although this latter and the median naked area extend well below the ambitus, the horizontal areas become narrower toward, and disappear at the ambitus. Enlarged secondary tubercles tend to form horizontal series on each plate below the ambitus, and the granules, often elongate, become much more closely spaced. The tubercles are strongly crenulate and the margins of their bosses may merge with irregular granules and appear finely scalloped.

Synopsis of Material: From the Tortachilla Limestone, Upper Eocene: 'Aldinga', P20212-4, P20215, P19239; AUGD17019, 17026, 17029 and twenty-six other specimens R. J. Foster Coll. From the Blanche Point Marl, Upper Eocene; 2 specimens R. J. Foster Coll.

Measurements:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
AUGD17026	23·0 mm	13·5 mm	7·5 mm	*c* 8·0 mm	13(14)	15(16)
P20212	22·0	14·5	6·5	7·5	12(13)	12(13)
AUGD17029	22·0	14·0	6·0	7·5	12(13)	14
P20214	16·0	8·5	—	6·0	11	11
P19239	15·0	9·5	—	6·0	12	11(12)

Remarks: There can be little doubt that Tate (*loc. cit.*) was referring to this species when he wrote concerning *'Psammechinus Woodsi'*. 'The species is represented in the Aldinga Cliffs by the *humilior* form . . . in which the secondary granulation is almost obliterated'.

Radiolus sp. indet.

(Pl. 5, fig. 11)

A group of diadematacoid radioles (P19841-54), from the 'Murray River Cliffs, Wongulla to Mannum', probably belong to one or other of the temnopleurid species described above, for their acetabula are strongly crenulate. They are comparatively long and tapering with oblique and expanded milled rings and short bases marked by longitudinal furrows continuous with the crenulations. They could belong to either *Asaphechinus murrayensi* or *A. princeps*, forms from the same horizon with strongly crenulate tubercles.

Two similar radioles (P19974-5) are also in the collection labelled as coming from the 'lower beds, Morgan'.

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Explanation of Plates

Plate 3

Figures × 5 unless otherwise stated.

Fig. 1-9—*Cryptechinus humilior* (Bittner). (1) Superambital view of ambulacrum of neotype P17966; (2) Apical system of large specimen P17969; (3) Apical system of highly sculptured specimen AUGD17016; 'Murray River Cliffs'; (4) Superambital view of P17968, a poorly sculptured test, showing granular ridges parallel to sutures along the interambulacral midzone; (5) Superambital view of P17967; (6) Oblique view of perignathic girdle P17971, × 2; (7) Oblique view of perignathic girdle F17970, × 2; (8) Superambital view of highly sculptured specimen AUGD17016, 'Murray River Cliffs'; (9) Smallest available specimen P17964. All except AUGD-17016 from 'Morgan', Batesfordian or Balcombian.

Plate 4

Figures × 1 unless otherwise stated.

Fig. 1-6—*Cryptechinus humilior* (Bittner). (1) Adapical; (2) Adoral; (3) Lateral views of P17969; (4) Adapical; (5) Adoral; (6) Lateral views of neotype P17966. Specimens from 'Morgan', Batesfordian or Balcombian.

Fig. 7-9, 14-15—*Tatechinus nudus* gen. et sp. nov. (7) Adapical; (8) Adoral; (9) Lateral views of holotype P20212; (14) Ambital; (15) Subambital views of AUGD17019, × 5. Specimens from 'Aldinga', Upper Eocene.

Fig. 10-13—*Grammechinus meridionalis* sp. nov. (10) Lateral view of holotype P19211; (11) Adoral view of P20213; (12) Superambital view of P20213, × 5; (13) Superambital view of P20213, × 5. Specimens from 'Aldinga', Port Willunga Beds, Janjukian to Batesfordian.

Plate 5

Figures × 1 unless otherwise stated.

Fig. 1-4, 6-7, 12—*Asaphechinus murrayensis* gen. et sp. nov. (1) Adapical; (2) Adoral; (3) Lateral views of holotype P18172; (4) Apical system of holotype, × 5; (6) Superambital; (7) Apical system of sculptured juvenile AUGD17017, × 5; (12) Superambital view of holotype, × 5. All specimens from Mannum Formation, Longfordian.

Fig. 8-10—*Asaphechinus princeps* sp. nov. (8) Adoral; (9) Lateral views of AUGD17018; (10) Superambital view of AUGD17018, × 5; 'Mannum', Longfordian.

Fig. 11—Indeterminate diadematacoid radioles P19841-P19845, 'Wongulla to Mannum', Longfordian, × 2.

PLATE 6

Figures × 1 unless otherwise stated.

Fig. 1-4, 8-12—*Asaphechinus singletoni* sp. nov. (1) Adoral; (2) Adapical; (3) Lateral views of holotype MUGD3490, 'Beaumaris', Cheltenhamian; (4) Lateral and internal views of two teeth MUGD3490C-D and upper surface of rotula MUGD-3490E, × 2; (8) Left; (9) Right pyramids MUGD3490A-B showing growth zones on the interpyramidal faces, × 2; (10) Perignathic girdle of holotype; (11) Superambital; (12) Oral view of holotype, × 5.

Fig. 5-7—*Asaphechinus tasmanensis* sp. nov. (5) Adoral view of P19043; (6) Adapical view of holotype P19042; (7) Ambital view of P19043, × 5. Specimens from 'Table Cape', Janjukian.

PLATE 7

Figures × 5 unless otherwise stated.

Fig. 1-13—*Orthologhus morganensis* sp. nov. (1) Adapical; (2) Lateral; (3) Adoral views of P17998, × 1; (4) Adapical; (5) Lateral; (6) Adoral views of holotype P17997, × 1; (7) Oblique view of perignathic girdle P18002, × 2; (8) Apical system of P18000; (9) Superambital view of a small specimen P18001; (10) Apical system of holotype; (11) Supcrambital view of same; (12) Superambital view of P17998; (13) Supcrambital view of P17999. Specimens from 'Morgan', Batesfordian or Balcombian.

Fig. 14-18—*Orthologhus lineatus* (Duncan). (14) Lateral; (15) Adoral views of holotype BM GSL14078, 'Mordialloc', Cheltenhamian, × 1; (16) Ambital view of holotype; (17) Superambital view of P23981; (18) Adoral view of P23981, 'Beaumaris' Cheltenhamian. (14), (15), 16) British Museum (Nat. Hist.) photographs.

PLATE 8

Figures × 5 unless otherwise stated.

Fig. 1-16—*Orthologhus woodsi* (Laube). (1) Adapical; (2) Lateral; (3) Adoral views of P18180, a low-tested form (var. *fascigar* Bittner), × 1; (4) Lateral view of P18179, × 1; (5) Super-ambital view of highly sculptured juvenile P18334; (6) Oblique view of girdle P18268, × 2; (7) Adapical view of P18178, × 1; (8) Adapical view of juvenile P18269; (9) Apical system of P18180; (10) Ambital view of P18180; (11) Superambital view of P18176; (12) Ambital view of P18586, 'Polyzoal limestone N of Bird Rock, Torquay', Longfordian; (13) Superambital view of juvenile P18331; (14) Superambital view of juvenile P18332; (15) Supcrambital view of juvenile P18333; (16) Ambital view of uncoated specimen P18609, showing traces of what is probably original colouration of the test, 'Pt. Danger', Batesfordian. Specimens from localities in the Longfordian Mannum Formation unless otherwise stated.

PLATE 9

Figures × 5 unless otherwise stated.

Fig. 1-7, 9, 11-14—*Orthologhus venustus* sp. nov. (1) Adapical; (2) Lateral; (3) Adoral views of P20124, 'Longford', ? Longfordian, × 1; (4) Adapical; (5) Lateral; (6) Adoral views of holotype MUGD3492, 'Brock Quarry, Glencoe', Batesfordian, × 1; (7) Oblique view of girdle MUGD3493, same locality, × 2; (9) Test fragment MUGD3494, same locality, × 2; (11) Apical system of P20124, Longford; (12) Superambital view of holotype; (13) Supcrambital view of P18745, a specimen with sculpture transitional between *venustus* and *woodsi*, 'Mouth of Spring Creek', Longfordian; (14) Superambital view of P20124, 'Longford'.

Fig. 8, 15—*Pseudechinus* sp. cf. *P. albocinctus* (Hutton). (8) Lateral view of P18367, 'Toorloo Arm', Bairnsdalian, × 1; (15) Superambital view of same.

Fig. 10—*Orthologhus lineatus* (Duncan). Superambital view of P18431, 'Orbost', Bairnsdalian (cf. Pl. 7, fig. 17).

PLATE 10

Figures × 5 unless otherwise stated.

Fig. 1-14—*Orthologhus pulchellus* (Bittner). (1) Adapical; (2) Lateral; (3) Adoral views of P17931 'Overland Corner', × 1; (4) Adapical view of P17986, × 1; (5) Adoral; (6) Adapical; (7) Lateral views of neotype, × 1; (8) Oblique view of girdle P17087 × 2; (9) Adapical view of juvenile P17980; (10) Superambital view of P17979; (11) Superambital view of P17984; (12) Superambital view of P17986;

(13) Superambital view of neotype P17983; (14) Superambital view of P17931. Specimens from 'Morgan', Batesfordian or Balcombian, unless otherwise stated.

PLATE 11

Figures × 2 unless otherwise stated.

Fig. 1-12—*Paradoxeehinus novus* Laube. (1) Adapical; (2) Adoral view of P18266 (♀); (3) Adapical view of P18223 (♂); (4) Superambital view of same, × 5; (5) Lateral view of broken specimen showing girdle and plates of apical depression P18175 (♀); (6) Oblique view of apical depression P18266 (♀); (7) Adapical view of P18224 (♂); (8) Adapical; (9) Adoral views of P18267 (♂); (10) Lateral; (11) Adapical views of P18243 (♀), × 5; (12) Superambital view of P18224 (♂), × 5. Specimens from the Longfordian Mannum Formation.

Fig. 13-21—*Orthoplus bittneri* nom. nov. (13) Apical System of P20489, × 5; (14) Broken specimen showing perignathic girdle P20473; (15) Adoral; (16) Adapical; (17) Lateral view of neotype P20488, × 1; (18) Lateral; (19) Adapical views of P20489, × 1; (20) Superambital view of neotype. × 5; (21) Ambital view of P20473, × 5. Specimens from the Upper Eocene Tortachilla Limestone at Aldinga.

PLATE 12

Figures × 1 unless otherwise stated.

Fig. 1—*Paradoxeehinus novus* Laube. Lateral view of holotype VNM9024.

Fig. 2—*Orthoplus woodsi* Laube. Superambital view of holotype VNM9019.

Fig. 3-4, 7—*Asaphechinus singletoni* sp. nov. (3) Lateral view of P23971; (4) Superambital view of same specimen; note granules aligned parallel to interambulacral midzone, × 5; (7) Ambital ambulacral and interambulacral plate of same, × 15. Beaumaris, Cheltenhamian.

Fig. 5—*Asapheehinus murrayensis* sp. nov. Subambital view of AUGD17021, × 5, '3 miles N. of Mannum', Longfordian.

Fig. 6—*Orthoplus lineatus* (Duncan). Superambital ornament of small specimen P23981, × 15.

PLATE 13

Figures × 15 unless otherwise stated.

Fig. 1—*Orthoplus woodsi* Laube. Ambital ornament AUGD17022, 'N. of Blanchetown', Longfordian, × 5.

Fig. 2-3, 5-7—*Orthoplus bittneri* nom. nov. Specimens chosen to show variation in sculpture. (2) UNE10565; (3) UNE10566; (5) UNE10567; (6) UNE10568; (7) UNE10569.

Fig. 4—*Asapheehinus singletoni* sp. nov. Apical system of a juvenile specimen P23969, 'Beaumaris', Cheltenhamian, × 5.

PLATE 14

Figures × 1 unless unless otherwise stated.

Fig. 1-3—*Asapheehinus princeps* sp. nov. (1) Lateral view of holotype AUGD17020, '3 miles N. of Mannum', Longfordian; (2) Enlargement of ambital ornament of holotype, × 5; (3) Peristome of holotype, × 15.

Fig. 4—*Orthoplus woodsi* (Laube). Superambital view of form with rare interambulacral midzones AUGD17023, '1½ miles N. of Nildottie', Longfordian.

Fig. 5-6—*Grammeehinus meridionalis* sp. nov. (5) Adapical view of AUGD17024; (6) Adoral view of AUGD17025; Specimens from Whitton Bluff, Upper Eocene.

Fig. 7—*Tateehinus nudus* gen. et sp. nov. Apical system and adapical ambulacra AUGD17026, 'Aldinga', Upper Eocene, × 15.

PLATE 15

Figures × 5 unless otherwise stated.

Fig. 1—*Orthoplus pulehellus* (Bittner). Apical system with ocular plate 1 just insert, AUGD17027, 'Morgan', Batesfordian or Balcombian.

Fig. 2—*Asapheehinus tasmanensis* sp. nov. Ambital view of damaged specimen P23984, 'Table Cape', Janjukian.

Fig. 3—*Orthoplus woodsi* (Laube). Apical system of specimen with ocular plate I insert, AUGD17028, 'Mannum', Longfordian.

Fig. 4—*Tatechinus nudus* gen. et sp. nov. Ambital view of AUGD17029 'Aldinga', Upper Eoeene, × 15.

Fig. 5—*Orthlophus woodsi* (Laube). Superambital seulpture of speeimen approaehing *O. pulchellus* AUGD17030, 'Mannum pumping station', Longfordian, × 15.

PLATE 16

Figures × 1 unless otherwise stated.

Fig. 1-6—*Evechinus palatus* sp. nov. (1) Adapieal; (2) Adoral; (3) Lateral views of holotype P23967; (4) Superambital view of holotype, × 5; (5) Portion of adoral surfaee of holotype. × 5; (6) Termination of adoral ambulaerum at the margin of the peristome of holotype, 'Beaumaris', Cheltenhamian.